Essays on Agricultural and Environmental Policy

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Abstract

This thesis consists of a summary and four papers. The first two papers address political economy and industrial organization aspects of agricultural policy, and the last two international aspects of environmental policy.

Paper [I] explains Common Agricultural Policy (CAP) subsidies to farmers by the influence of farmer interest-groups with an EU-wide membership. The analysis is based on panel-data for fifteen commodities over the period 1986-2003. Because the CAP is set as an overall EU policy, effective lobbying presents a collective action problem to the farmers in the EU as a whole. Indicators of lobbying, which are based on this perception, are found to explain part of the variation in agricultural support.

In Paper [II], the Bresnahan-Lau framework is used to analyze whether policy reforms, i.e. the two-price system (an input quota, 1986-1991) and a general deregulation of dairy policy (1991-1994) had any market power effects on the Swedish butter market. The results show that the null hypothesis of no market power cannot be rejected, for any of the specific policy reforms, at any reasonable significance level.

Paper [III] concerns the welfare consequences of environmental policy cooperation. It is assumed that countries finance their public expenditures by using distortionary taxes, and that they differ with respect to competition in the labor market. It is shown how the welfare effect of an increase in the expenditures on abatement depends on changes in the environmental damage, employment and work hours. The welfare effect is also related to the strategic interaction among the countries in the prereform equilibrium.

In Paper [IV] environmental policy in an economic federation, where each national government faces a mixed tax problem, is addressed. It is assumed that the federal government sets emission targets, which are implemented at the national level. It is also assumed that the economic federation is decentralized. The results highlight a strategic role of income and commodity taxation, i.e. each country uses its policy instruments, at least in part, to influence the emission target.

Keywords: agricultural policy, political economy, lobbying, cooperatives, market power, policy cooperation, distortionary taxes, labor market, Nash game, Stackelberg game, income and commodity taxation, economic federation, environmental policy

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Umeå, October, 2007
Thomas Jonsson

This thesis consists of a summary and the following four papers:

[I] Jonsson, T. (2007), Collective Action and Common Agricultural Policy Lobbying: Evidence of Euro-Group Influence, Umeå Economic Studies 713.

[II] Jonsson, T. (2007), Market Power Effects of Supply Control and Dairy Market Deregulation, Umeå Economic Studies 721.

[III] Aronsson, T., Jonsson, T. and Sjögren, T. (2006). International Environmental Policy Reforms, Tax Distortions, and the Labor Market, FinanzArchiv 62, 199-217. (Reprinted with kind permission of Mohr Siebeck)

[IV] Aronsson, T., Jonsson, T. and Sjögren, T. (2006). Environmental Policy and Optimal Taxation in a Decentralized Economic Federation, FinanzArchiv 62, 437-454. (Reprinted with kind permission of Mohr Siebeck)

1 Introduction

This thesis consists of four self-contained papers.

Papers [I] and [II] are empirically orientated and cover two interrelated topics; political economy and industrial organization aspects of agricultural policy. Paper [I] studies the political economy of the Common Agricultural Policy (CAP) of the European Union (EU), and more specifically deals with lobbying by EU-wide interest groups. In Paper [II], Swedish data is used to study whether input supply control and the 1991 general dairy market deregulation had any effects on the ability of dairy cooperatives to exercise market power in the Swedish butter market.

Papers [III] and [IV] are theoretical and focus on international aspects of environmental policy. Paper [III] concerns the welfare consequences of environmental policy cooperation, where the countries differ with respect to competition in the labor market, and Paper [IV] deals with environmental policy in a decentralized economic federation.

The remaining part of this introductory chapter is structured as follows. Section 2 presents the background to and summarizes Papers [I] and [II]. Section 3 presents the background to and summarizes Papers [III] and [IV].

2 Agricultural Policy

Developed countries tend to support their producers of agricultural commodities heavily. For example, the CAP consumes about 40% of the total EU budget, while the agricultural sector employs less than 2% of the EU's workforce. The first two papers in this thesis are attempts to shed some light on the determinants and consequences of the support to agriculture. Paper [I] deals with determinants of agricultural subsidies. More specifically, the study assesses the influence executed by transnational EU lobby groups (so called Euro-groups) on the CAP. As such, it relates to the literature on the political economy aspects of agriculture. The second paper concerns the effects of agricultural support policies. More specifically, the problem addressed is whether such policies made it possible for domestic food producers to exercise market power. The paper studies the case of Swedish pre-EU agricultural policies, and whether specific reforms had any market power effects for dairy cooperatives on the market for butter. This paper is primarily related to the literature on cooperatives and competition.

In the following, these two strands of the literature are reviewed and the respective paper summarized.

2.1 The Political Economy of Agriculture

Olson (1965) developed a framework of analysis (and applied it extensively to farm policy) that depicts a passive government responding to lobby activities by interest groups, who organize themselves for collective action. The policy outcome hinges critically on the ability to overcome costs of organization and free-riding. According to this framework, successful collective action is related to demographic factors, where the number of firms within the industry attempting to organize itself is the main indicator. The intuition is that the more firms there are within the industry, ceteris paribus, the greater the incentives for the individual firm to free-ride. Thus, the more likely it is that the effort made by any such firm is suboptimally low from the perspective of the industry as a whole. A negative relationship between the number of farms and agricultural support has been found by Olper (1998) on national European data, Helfand (2000) on Brazilian data, and Miller (1991), Fulginiti and Shogren (1992), Sarker et al. (1993), van Bastelaer (1998) and Swinnen et al. (2000) on cross-country data.

A second indicator for successful collective action has been derived by Bombardini (2005). According to her results, and given the size of the industry as a whole, the less homogenous the firms are in size, the greater the overall lobbying effort. This is because of certain minimal fixed-costs of lobbying, which only the larger firms may be able to cover. With a more homogenous grouping, none may be able or motivated to lobby, whereas with a more heterogenous grouping at least large firms may be able to. Hence, the size-heterogeneity of an industry is a potential determinant of lobbying effort. Bombardini (2005) confirms this result empirically.

Although a large empirical literature exists on assessing the influence of lobby groups on agricultural policy, there has not been much research dealing with the CAP. One exception is Olper (1998), who finds that indicators of the national lobbying-strenght of farmers explained part of the variation in total agricultural support (CAP support and domestic support) in seven EU member states. However, as indicated in several studies (predominantely within the area of political science; see e.g. Pinjenburg, 1998 and Woll, 2006), the influence of Euro-groups, i.e. lobbying groups with an EU-wide member base, plays a significant role in the CAP lobbying structure. This idea constitutes a starting point for Paper [I].

2.2 Cooperatives and Competition

A marketing cooperative is an arrangement that enables a large number of small sellers to coordinate strategies (such as price) when selling a good and to exploit returns to scale. This arrangement is normally considered legal and, in many cases, is actively promoted by the legislative authorities, even though marketing cooperatives have many features in common with marketing cartels.

However, the marketing cooperatives are typically organized in such a way that their ability to exercise market power is limited. Most marketing cooperatives' output levels are determined by the production decisions made individually by each member, and membership in such cooperatives is voluntary. As shown by e.g. Sexton and Lavoie (2001), this way of organizing a marketing cooperative makes it generally ill-suited to exercise market power. On the other hand, if the cooperative is able to restrict supply, a dominant market position may be used for anticompetitive purposes. Supply may be restricted through quotas imposed on the members of the cooperative or via price discrimination. Bergman (1997), building on a model by Helmberger and Hoos (1962), shows that price discrimination between a foreign market, where the cooperative is a price taker, and the domestic market where the cooperative has a dominant market position, may lead to a price higher than marginal cost on the domestic market.

There exists a vast literature on the extent of imperfect competition in the food industry (for an overview, see Sheldon and Sperling, 2003). However, for dairy products there is only a limited number of studies. Gohin and Guyomard (2000) study the french dairy retail industry, and they strongly reject the hypothesis that French food retail firms behave competitively. Madhavan et al. (1994) find evidence of market power exercised by American dairy cooperatives in monopoly position. According to their findings, the dairy cooperatives discriminate between the markets for processed milk products, since the price elasticity of demand differs between markets.

In the Swedish dairy market, prior to the EU accession in 1995, attempts to control domestic supply of dairy products were made. In 1986 a voluntary quota (referred to as the "two-price system") was established. The two-price system prescribed an individual quota to each farmer participating within the program. Moreover, prior to 1991 when Swedish dairy policy was regulated nationally, export of butter was subsidized. Hedberg (2002) measures the extent of imperfect competition in the Swedish dairy market for one particular year, 1990. She finds no evidence of mark-up over marginal cost. In fact, she finds that prices of fluid milk, cheese, butter and milk powder are close to modelled competitive prices. On the other hand, Bergman (1997) finds evidence of price discrimination between domestic and foreign consumers in seven OECD countries (including Sweden).

When measuring market power, it has been common since the late 1980's to use structural econometric models. The methodology developed by Bresnahan-Lau (Bresnahan, 1982 and Lau, 1982) has become popular, particularly in research on the competitiveness of food markets (see e.g. Applebaum, 1982; Lopez, 1984; Schroeter and Azzam, 1990 and Bettendorf and Verboven, 2000). The Bresnahan-Lau method measures the conjectural variation elasticity at the industry level, which can be interpreted as the average of the individual firm's conjectural variation elasticities. The latter is a measure of all firms' output responses to a price change relative to a change in the individual supplier's output, as conjectured by this individual supplier. This methodological framework provides the basis for Paper [II].

2.3 Summary of Papers [I] and [II]

Paper [I]: Collective Action and Common Agricultural Policy Lobbying: Evidence of Euro-group Influence

The purpose of Paper [I] is to assess the influence on CAP exercised by farmer interest groups with an EU-wide member base, Euro-groups. The main motivation for studying EU-wide lobbying in the context of the CAP is that an implemented regulation becomes a public good for the beneficiaries. With the CAP, the collective-action problem thus becomes EU-wide.

The study uses a panel dataset with a total of 270 observations, which is based on fifteen commodity groups over the 18-year period 1986-2003. Following earlier literature, agricultural support is related to indicators of the effectiveness of lobbying. The main indicators of effective lobbying are the number of farms and their size-dispersion.

The number of farms producing a given commodity and the size-heterogeneity of the industry are found to explain part of the variation in support for that commodity. In addition, the effects are in line with the theoretical predictions, i.e. the number of farms has a negative effect and size-dispersion a positive effect on agricultural support.

This suggests that Euro-group lobbying has been able to influence the CAP. To some extent, the results diverge from what is found in earlier studies, particularly on American data, where an inverted U-shaped relationship between subsidies and number of farms is found. The American results may combine a variety of policy-mechanisms. Politicians favour large groups because of their voting power, so the inverted-U relationship is one possible outcome as the voting-power effect (better with large numbers) counteracts the collective-action effect (better with small numbers). But the voting-power explanation is not equally applicable to the CAP, since supranational EU decision-making is more detached from voter influence. The results in Paper [I] confirm this.

Moreover, some evidence is also found suggesting that Euro-groups, representing different food commodities, compete for resources within a given CAP budget.

Paper [II]: Market Power Effects of Supply Control and Dairy Market Deregulation

The purpose of Paper [II] is to analyze the extent to which Swedish dairy cooperatives were exercising market power on the market for butter prior to the EU accession in 1995. The study period is 1980-1994, mainly due to the specific dairy policy reforms that took place over that time interval. Until 1991, prices of dairy products were regulated, and butter was subsidized to make exports to the world market easier. Moreover, during the period 1986-1991, a voluntary quota for raw milk input supply to processing dairies was in operation. Since butter was the sole dairy good exported, it is of special interest from a market power point of view. Together with the input supply quota, the ability to price disriminate may have given the Swedish dairy cooperatives abilities to exercise market power on the domestic market. Since only data for retail price and quantity are available for processed dairy products, changes in dairy regulations over the period of study are accounted for in order to distinguish the market power exercised by cooperatives from that exercised by retailers.

The Bresnahan-Lau method is adopted to measure market power both in terms of a static and a dynamic (error correction) specification. Due to its ability to account for non-stationarity among the variables and for autocorrelation, the dynamic model is preferred. No significant market power effects due to the specific reforms are found. Possible explanations for the lack of significant market power effects are that the farmers had a weak bargaining position (relative to the consumer representatives) when the prices of dairy products were decided upon; that the quota rule was inefficient, or that the butter price was affected by competition from substitute goods.

3 Environmental Policy

Environmental problems are often transboundary, meaning that emissions generated by a country do not only affect the welfare of the domestic residents; the emissions also affect the welfare of residents in other countries. To deal with such problems, some kind of cooperation between countries is generally required. In the international political scene of today, we see several international arrangements, ranging from voluntary agreements between politically independent countries, such as the Kyoto protocol, to arrangements within given institutional structures, such as the environmental policy cooperation within the EU. The last two papers in this thesis address issues related to transboundary environmental problems in a policy cooperation context. Paper [III] deals with environmental policy cooperation between two (independent) countries, where the countries differ with respect to competitiveness in the labor market. Paper [IV] addresses environmental policy within a more structured institutional environment, i.e. an economic federation with decentralized leadership.

The existing literature in each of those two fields is reviewed briefly below and, thereafter, the two papers are summarized.

3.1 Environmental Policy Reforms in the Presence of other Tax Distortions

Market economies are characterized by a number of distortions, each of which may influence the welfare effects of projects aimed at improving the environment. How distortions in the labor market are interrelated with environmental externalities in this context has been thoroughly analyzed in the literature.

In particular, the idea that governments can use the revenues from pollution taxes to decrease other, distortionary taxes, such as e.g. the labor income tax, has received much attention (see e.g. Oates, 1991, Pearce, 1991 and Aronsson 1999). However, as shown by e.g. Bovenberg and de Mooij (1994) and Bovenberg and Goulder (1996), environmental taxes are likely to exacerbate, rather than alleviate, preexisting tax distortions - even if revenues are used to cut preexisting distortionary taxes. This body of literature is typically based on one-country model economies, in which transboundary environmental problems do not arise.[1] One exception is Hoel (1997), who considers international environmental policy in combination with imperfect competition in the labor market. Hoel studies whether international environmental targets should be supplemented by coordination of the policies used to implement these targets. Another exception is Aronsson and Blomquist (2003), who consider redistribution and environmental policy in a two-country model, where each national government faces a mixed tax problem.

Since countries typically differ with respect to preexisting distortions, policy coordination may result in asymmetries regarding the welfare consequences for the countries involved. For instance, European labor markets are to some extent characterized by union wage formation, whereas the labor market in the U.S. bears more resemblence to a competitive market. Since unemployment is a major social problem in many countries, the labor market is likely to play an important role in the choice of economic policy (including environmental policy) at the national level. Paper [III] adds to the environmental policy coordination literature in this particular context.

3.2 Environmental Policy and Federalism

An economic federation is often described as a multi-level government structure, where each level has its own responsibilities and policy instruments. This can be exemplified by the national and lower level governments within a given country as well as by supranational economic federation such as the EU. Economic federations in the world today plots a heterogenous picture, where the institutional structures typically differ with respect to the committment power

[1] See also the literature dealing with environmental policy reforms in economices with imperfect competition in the labor market, e.g. Schneider (1997), Bovenberg and van der Ploeg (1998), and Koskela and Schöb (1999)

that might be exercised by the different levels of government. For instance, whereas the public decision-structure in a given country might be reasonably well described in terms of an economic federation with centralized leadership (provided that the central government is able to commit to its policies), the EU may exemplify an economic federation with decentralized leadership.

Earlier research on environmental policy in economies with transboundary environmental problems do not pay so much attention to the institutional structure when it comes to implementing a supranational arrangement. Instead earlier literature that applies theories of optimal taxation to economies with transboundary environmental problems typically compares the outcome of a noncooperative policy regime with the outcome of full cooperation. Examples are van der Ploeg and de Zeeuw (1992), Aronsson and Löfgren (2000) and Aronsson and Blomquist (2003).

On the other hand, in their studies on economic policy and transboundary environmental problems, Silva and Caplan (1997) and Caplan and Silva (1999) pay explicit attention to the role played by a federal decision structure, involving a federal government and lower level (e.g. national or regional) governments. The federal government is assumed to control one specific policy instrument (e.g. abatement), whereas lower level of governments are assumed to control another (e.g. environmental taxes). In addition, the economic federation may either be centralized or decentralized[2], depending on which level is able to make credible commitments (and they use the EU to exemplify a decentralized economic federation). In their studies, a major purpose is to characterize the environmental policy outcomes on the basis of (i) whether the economic federation is centralized or decentralized, and (ii) how the control over policy instruments is distributed between the levels of government.

This constitutes a starting point for Paper [IV], which deals with environmental policy and mixed taxation in an economic federation with decentralized leadership.

[2] Other than environmental policy, studies concerning economic federation with decentralized leadership focus on public good provision (Caplan et al., 2000), tax competition (Köthenburger, 2004) and redistribution (Aronsson, 2007).

3.3 Summary of Papers [III] and [IV]

Paper [III]: International Environmental Policy Reforms, Tax Distortions, and the Labor Market

Paper [III] concerns the welfare effects of environmental policy reforms in a framework with transboundary environmental problems, preexisting tax distortions and imperfect competition in the labor market, and the analysis is based on a general-equilibrium model of a two-country economy. It is assumed that the countries finance their public expenditures by using distortionary taxes, and that they differ with respect to competition in the labor market. The contribution is to characterize the cost-benefit rule associated with environmental policy cooperation. The paper thus provides an understanding of the mechanisms that determine the welfare effects of such agreements.

The study shows how the welfare effect of the policy reform depends on changes in environmental damage, employment, and work hours. It also relates the welfare effect to the strategic interaction among the countries in the prereform equilibrium. First, a general cost-benefit rule that does not necessarily require that public policy be optimally chosen on a national basis prior to the reform is derived. Second, a situation is considered where the prereform equilibrium is a non-cooperative Nash equilibrium, implying that each national government has made an optimal choice conditional on the private and public decision variables in the other country. Finally, the welfare effects of policy cooperation under the assumption that the prereform equilibrium is the outcome of a Stackelberg game is derived.

Paper [IV]: Environmental Policy and Optimal Taxation in a Decentralized Economic Federation

This paper deals with environmental policy in the context of a mixed tax problem facing each national government in an economic federation. It is assumed that the federal government sets emission targets, which are implemented at the national level. It is further assumed that the federation is decentralized, meaning that the national governments are first movers *vis-à-vis* the federal government. The model is inspired by the decision structure underlying the environmental policy within the EU.

The purpose is to characterize the optimal tax structure chosen by the national governments, and the results suggest a strategic motive for tax policy not discussed in earlier literature: if the lower-level (national) governments are able to commit to their policies, and the federal outcome is conditioned on the policy variables decided upon at the national level, tax policy at the national level will be used, in part, to affect the targets decided upon at the federal level. This has several implications: first, commodity taxes do not satisfy the so-called additivity property often emphasized in the literature[3], and, second, it provides an argument for using distortionary labor income taxation. The basic intuition behind the lack of additivity is that the national government has fewer policy instrument at its disposal than it has variables to control. The non-zero marginal income tax rate (set at the national level) reflects a combination of two motives: (i) the desire to offset distortions due to commodity taxation, and (ii) the desire to relax the federal emission target.

[3] See e.g. Sandmo (1975).

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I

Collective Action and Common Agricultural Policy Lobbying: Evidence of Euro-Group Influence

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Abstract

This paper attempts to explain Common Agricultural Policy (CAP) subsidies to farmers by the influence of farmer interest-groups with an EU-wide membership (so called Euro-groups). The analysis is based on panel-data for fifteen commodities over the period 1986-2003. Because the CAP is set as an overall EU policy, effective lobbying presents a collective action problem to the farmers in the EU as a whole. Indicators of lobbying, which are based on this perception, are found to explain part of the variation in agricultural support, suggesting that farmer Euro-groups influence agricultural policy within the EU.

Keywords: agricultural policy, political economy, lobbying.

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1 Introduction

The Common Agricultural Policy (CAP) costs European taxpayers over 40 billion Euro per year, or about 40% of the total European Union (EU) budget, while agriculture employs less than 2% of the EU's workforce. Moreover, about 80% of EU agricultural subsidies are paid to the richest 20% of farmers (Economist, 2005; Court of Auditors, 2005; Kay, 1998). It is not far-fetched to assume that these subsidies are largely a consequence of political activities (lobbying) organized by the beneficiaries. Empirical studies of American data show that indicators of the ability to lobby efficiently are important determinants of agricultural subsidies in the U.S.[1] But there has not been much research dealing with political economy determinants of the CAP. One exception is Olper (1998) who finds that indicators of the national lobbying-strength of farmers explained part of the variation in total agricultural support (including CAP levels) in a panel of seven EU member-states over fourteen years.[2]

However, the influence of national (as opposed to EU-wide) lobbying groups may not fully capture the effect of lobbying on the CAP. The influence of lobbying groups with an EU-wide membership ("Euro-groups"[3]) must also be considered. The present paper assesses this influence. The CAP is analyzed separately from complementary national policies, using variables indicating the effectiveness of EU-wide lobbying groups. The study is based on a panel dataset with a total of 270 observations on fifteen commodity groups over the 18-year period 1986-2003.

The main motivation for studying EU-wide lobbying is that an implemented regulation becomes a public good to the beneficiaries. Consider a group of

[1] De Gorter and Swinnen (2002) review the political economy literature on agricultural policy. The main reference on American farm-policy is Gardner (1987), but determinants of U.S. farm subsidies have also been studied by Lopez (2001), Gawande (2005), and Gawande and Hoekman (2006). Studies based on cross-country data also show that indicators of lobbying efficiency have an influence on agricultural support (e.g. Miller, 1991; van Bastelaer, 1998; and Swinnen et al., 2000).

[2] Other studies have predominantly focused on the decision-making structure of the CAP by addressing its specific features theoretically: Burton (1985) analyzed implementation of the EC milk quota, and Gallagher (1988) investigated implementation of an EU co-responsability levy for the grain farmers.

[3] The term "Euro-groups" is borrowed from van der Zee (1997) and is defined as "transnational EC-wide interest-groups". This definition will also be employed here. Van der Zee also presents lists of the Euro-groups involved in lobbying for CAP subsidies.

farmers successful in their effort to obtain a subsidy for the good they produce. Since they cannot exclude other farmers who produce the same good, there can be free-riders who contribute nothing but enjoy the fruits of lobbying conducted by others, a classic collective action problem (Olson, 1965). With the CAP, the collective-action problem would be EU-wide. If beef farmers in France successfully lobby for a subsidy, beef farmers in Greece would benefit as well.

A study of EU-wide lobbying could also be motivated by considering the CAP decision making structure. The EU Commission initiates CAP legislation and frequently uses the special knowledge of interest groups, even encouraging the establishment of EU-wide agricultural interest-groups (van der Zee, 1997). This demand for outside expertise arises because the Commission bureaucracy is relatively small compared to that of national governments. The expertise provided by Euro-groups is more valuable to the Commission than that of national lobbying groups, since it represent the interests of all beneficiaries of the policy (Mazey and Richardson, 1993). Hence, "there exists a natural tendency for the Commission to deal with Euro-groups" (van der Zee, 1997). However, although Euro-groups are a more or less official part of CAP policy-making, some authors doubt their influence. Field and Fulton (1994) characterize Euro-groups as "ineffective at the supranational level". A formal analysis of the determinants of CAP subsidies may help to resolve this debate.

Following earlier literature, this paper relates the level of agricultural support to indicators of the effectiveness of lobbying. Besides the subsidies themselves, the main indicators of the effectiveness of lobbying are the number of firms and their size-dispersion. The results imply that farmer Euro-groups have an influence on the CAP.

The outline of the paper is as follows. Section 2 briefly reviews the formal and informal lobbying structures regarding the CAP, while Section 3 presents a simple theoretical model for lobbying group influence on agricultural support. Section 4 then discusses the literature on collective action in order to distinguish proxy-variables for measuring the effectiveness of lobbying. Section 5 describes the data and the variables included in the empirical model. Section 6 describes the empirical model and Section 7 presents the results. Finally, Section 8 summarizes and draws conclusions.

2 A Brief Overview of the CAP Lobbying Structures

Euro-groups enjoy an exclusive position in the EU political process, as the establishment by the Commission of formal advisory committees has institutionalized their role, particularly in the formation of agricultural policy (van der Zee, 1997). Their activities with regard to the CAP are organized through the main umbrella interest-group organization for agricultural producers, COPA-COGECA, the memberbase of which consists mainly of national producer associations.[4] The committees are only consultative and have no official power, however, so that lobbyists consider their formal influence to be negligible (Mazey and Richardson, 1993). Instead the committees establish access for further, less formal contacts with decision-makers.

This informal lobbying is often conducted via *ad hoc* coalitions (Pinjenburg, 1998; Berry, 1989). Compared with the institutionalized committees informal lobbying may pose a greater collective action problem, since support for lobbying has to be built from among the presumptive beneficiaries. Summarizing a number of studies which have discussed the (possibly high) organization-cost carried by informal lobbying groups, Woll (2006, p 459) concludes that "effective collective action at the supranational level is difficult even for groups of large and powerful actors." However, the fact that Euro-groups still use these methods indicates that the benefits of doing so are perceived to outweigh the costs.

Another feature of CAP decision making is the strong position of the Council of Agricultural Ministers. The Council of Agricultural Ministers represents the member-state governments in the CAP decision making process. For them to become effective, the Council has to approve Commission proposals by a qualified majority. This means that lobby-groups have to focus their efforts at both the national and the EU-level (Runge and von Witzke, 1987). Nevertheless, the collective-action problem they face is EU-wide. Successful lobbying efforts will result in policies effective throughout the EU, so the incentives of producers

[4] COPA-COEGA is the merger of the two former separate EU producer organizations COPA (*Comité des Organisations Professionnelles Agricoles de L'Union Européenne*, Committee of Professional Agricultural Organisations in the European Union) and COGECA (*Confédération Générale des Coopératives Agricoles de l'Union Européenne*, General Confederation of Agricultural Co-operatives in the European Union)

throughout the EU to participate in lobbying must be considered.

3 Modelling CAP Lobbying

Gardner (1987) considers a unitary government which maximizes a weighted sum of consumer's surplus and producer rents for agricultural commodites in a partial-equilibrium model. The resulting support-level for each commodity is a function of lobbying effectiveness, measured by various group characteristics. Following Gardner, it is assumed here that policy-makers face a redistribution problem between consumers and producers when setting agricultural support-levels. The benefit for consumers of commodity i - given by $C\left(s^i\right)$, where s^i is the level of agricultural support - is assumed to be separable from that obtained from other commodities. The rent to the producers is given by $P\left(s^i, \mathbf{X}^i\right)$, where $\mathbf{X}^i$ is a vector of commodity- or producer-specific exogenous variables. The government objective function can then be written as

$$\Omega^i = C\left(s^i\right) + \theta^i P\left(s^i, \mathbf{X}^i\right) \tag{1}$$

where θ^i (≥ 1) is the weight attached to producers of commodity i, determined by how effective their lobbying is. Note that a subsidy could benefit both consumers and producers, whereas the cost would be carried by taxpayers. Hence, there is an implicit budget-restriction in the redistribution problem for each commodity as written in equation (1). Maximization of equation (1) with respect to s^i yields

$$s^i = f\left(\theta^i, \mathbf{X}^i\right) \tag{2}$$

assuming, in line with earlier literature, that there are no cross-commodity linkages (Gardner, 1987).

However, if resources available for supporting agriculture as a whole are scarce, so that increasing support to one group would mean decreased support to one or more other groups, then there would be an immediate link between the lobbying activities of one group and the support-levels attained by others (e.g. Gawande and Hoekman, 2006).[5] With the budget-constraint written as

$$\tau = \sum_i s^i \tag{3}$$

[5] Olper (1998) uses data aggregated over commodity groups, and thus do not face this issue.

where τ is the exogenously given total expenditure for the CAP as a whole, and assuming that the overall objective is the sum of the product-specific objectives, i.e., $\Omega = \Omega^1 + ... + \Omega^n$, then the resulting expression for s^i is

$$s^i = f\left(\theta^1, ..., \theta^n, \mathbf{X}^1, ...\mathbf{X}^n, \tau\right) \tag{4}$$

for $i = 1, ..., n$. The empirical specification below includes the possibility of such cross-commodity linkages.

4 Collective Action

To find operative measures of θ^i, the group-characteristics that results in effective lobbying, the theory of collective action (Olson, 1965), which builds on the observation that political regulations are public goods for those affected, is applied to the CAP.

Consider a regulation guaranteeing a higher price for a particular agricultural commodity, so that any and all producers of the commodity benefit but may or may not choose to participate in lobbying for the regulation. In a Nash equilibrium, each firm will lobby up to the point where its marginal benefit from the regulation equals its marginal cost of lobbying, taking the efforts of other firms as given, and the overall level of lobbying will be sub-optimal. However, some producer-groups lobby more effectively than others, which may depend on characteristics of those groups.

The literature suggests two characteristics of producer-groups as particularly important indicators of the overall level of lobbying-efforts (Magee et al., 1989 and Bombardini, 2005);

- *Number of firms.* Other things equal, the fewer the number of firms, the greater will be the overall lobbying effort. In the case of a monopoly, the owners of this particular firm benefit completely from any subsidy its lobbying effort can generate. The more firms there are, however, the less visable will be the outcome of efforts undertaken by a single firm, and the more likely it is that the effort made by any such firm is suboptimally low from the perspective of the industry as a whole. Transaction costs of organization are also higher with more firms, while selective incentives, penalizing those who do not contribute and rewarding those who do, become more difficult.

- *Size-heterogeneity.* Other things equal, the less homogenous are the producers in size, the greater will be the overall lobbying effort. This is because of certain minimal "fixed-costs" of lobbying (Bombardini, 2005), which only the larger firms will be able to (or motivated to) cover. With a more homogenous grouping, none may be able or motivated to lobby, whereas with a more heterogenous grouping at least large producers may.

Earlier studies have confirmed these characteristics as indicators of lobbying-effort (and effect) at the national level. Using national European data Olper (1998) finds a negative relationship between the number of farms and agricultural support; as do Helfand (2000) on Brazilian data, and Miller (1991), Fulginity and Shogren (1992), Sarker et al. (1993), van Bastelaer (1998) and Swinnen et al. (2000) on cross-country data. The effect of firm-size on support-levels is not as well documented but, using American data on non-agricultural as well as agricultural products, Bombardini (2005) finds that greater size-heterogeneity correlated with more support.

5 Data and Measurement

The econometric analysis covers 15 commodities - listed in Table 1, along with their 2003 shares of total CAP support - over the period 1986-2003.

Table 1. EU farm commodities and their share of total CAP support, 2003[a]

beef	0.188	sugar	0.027
milk	0.142	durum wheat	0.025
coarse grains	0.078	maize	0.025
common wheat	0.059	oilseeds	0.017
pigmeat	0.050	oats	0.009
barley	0.044	rice	0.002
sheepmeat	0.038	eggs	0.001
poultrymeat	0.029	total	0.735

[a]Some of the commodities subject to support - primarily fruits and vegetables, tobacco, and cotton - are excluded due to lack of data.

The dependent variable is producer support in percent of total revenues, based on annual producer support estimates (PSE), available only since 1986. PSE, an aggregate measure of the annual monetary value of gross transfers to producers, includes both implicit and explicit payments, such as guaranteed price caps on inputs and guaranteed price-floors on outputs, tax-exemptions and direct payments.

As key regressors, the number of farms producing commodity i in the EU and their size-heterogeneity are used, corresponding to the collective action indicators discussed above. Table A1 in Appendix describes the variables and data sources.

Four control variables are included; geographical concentration of production by region; the relative market-price; output per producer and annual CAP expenditures. Geographical concentration of production is measured by a Herfindahl index. Complete concentration in one region would generate a Herfindahl index of 1, whereas a less concentrated industry would yield a lower index. The inclusion of geographical concentration is to control for the additional cost of organizing lobbying because of geographical dispersion. Turning to the measures of relative market price and output per producer, one of the main objectives of the CAP is to ensure "a reasonable standard of living for the agricultural population" (OEEC, 1957: first paragraph of Article 39 of the Treaty of Rome), which presumably means high and stable income. Relative market price and output per producer are thus included as indicators of short-run agricultural income. Relative market-price is hypothesized to have an inverse effect on support per unit of output because, given output, a higher price means higher income and thus lower need for support. Output per producer is also hypothesized to have an inverse effect on support, because at a given price, more output means higher income and lower need for support. In the regressions, these two variables are lagged one period to reduce endogeneity arising from the fact that the dependent variable, producer support in percent of total revenues, causes changes in income. Finally, as discussed earlier, an effective budget-restriction on CAP expenditures would give rise to cross-commodity linkages. In order to test for such effects, the total CAP expenditures are included as an additional variable, as are collective-action and industry-characteristics for all commodities other than the one tested. This is discussed further in the next section.

Descriptive statistics for the variables used in the estimation are presented in Table 2.

Table 2. Summary statistics

Variable	Mean	Std. dev.	Min.	Max.	Expected sign
estimated support (PSE)	45.68	18.14	-2.84[a]	76.78	
number of farms	1180.0	757.5	22.66	3631	(-)
size-heterogeneity	33.49	30.62	8.68	142.9	(+)
geographical conc.	0.047	0.039	0.04	0.22	(+)
relative market-price	370.7	474.9	8.53	1967	(-)
output per producer	0.041	0.042	0.001	0.20	(-)
CAP expenditures	46023	12258	23382	61058	(+)
sum. number of farms	16520	3767	10328	25922	(+)
sum. size-heterogeneity	468.8	53.01	339.3	574.0	(-)
sum. geographical conc.	0.658	0.055	0.50	0.77	(-)
sum. relative market-pr.	16.12	1.70	9.97	17.88	(+)
sum. output/producer	0.029	0.087	0.012	0.048	(+)

[a]There are two negative observations for the PSE, pigmeat (1992) and eggs (1994). This negative post in the aggregate PSE measure is a result of penalties for not respecting production quotas.

6 Empirical Regression Model

The data available restricts the choice of model to be estimated. For each of the fifteen commodities, seventeen annual observations are available. The dataset could thus be considered as a long (and narrow) panel, i.e. one could estimate a separate equation for each commodity. However, only seven original observations per commodity are available for most of the explanatory variables (see Appendix). Hence, a pooled data model seems most appropriate. Gardner (1987), Olper (1998) and van Bastelaer (1998) all estimated similar pooled-data models.

The model can be expressed as

$$PSE_{it} = \alpha_i + \sum_k \beta^k X_{it}^k + \delta_t + \varepsilon_{it} \tag{5}$$

where subscript i denotes the commodity and subscript t the year, while the superscript k refers to the kth explanatory variable.

A linear-in-variables model was estimated (results not included here) with no statistically significant collective action effects found. However, F-tests (in the fixed effects model) and χ^2-tests (in the random effects model) showed that including the squares of the collective-action variables, number of farms and size-heterogeneity, increased the explanatory power of the model (Table 3, below).[6] Since the theory provides no guidance regarding functional form, this more general specification is used. The possibility of interaction effects between the key regressors is also allowed (specification 3).

Equation (5) contains commodity-specific and time-specific effects and F-tests and χ^2-tests support the inclusion of such effects into the model. Commodity specific effects may capture, among other things, the cost of redistribution due to differences among commodities with respect to demand and supply elasticities. The time specific effects are likely to capture structural shifts of policy. In 1992 price support policies were to a large extent replaced by direct payments to farmers (as was the effect of the Agenda 2000 reform). The enlargement in 1995, which added Sweden, Finland and Austria as new members, represents such a shift as well.

A Hausman specification-test suggests that the fixed-effects estimator is better than the random-effects estimator in the second, third and fourth specifications, but not in the first (Table 3, below). Serial correlation and groupwise-heteroskedasticity is found in all specifications and the t-values are calculated using robust standard errors to account for that.

Cross-commodity linkages, for the collective-action and control variables, are allowed in specification 4, by including total CAP-expenditures and six cross-commodity variables. Each such cross-commodity variable is measured as the sum over all commodities other than commodity i of the original variable (Table 2 above shows descriptive statistics for the cross-commodity variables). Where the original variables are lagged, so are the summed variables. By summing the variables, it is assumed, for example, that the number of farms producing commodities j and k affect support for commodity i in the same way. This simplification is used in order to avoid the multicollinearity which would have otherwise resulted.

[6] In order to reduce the multicollinearity that may arise when such transformations of explanatory variables are used, the average of the variable was subtracted before taking the square; i.e., $nfarm^2$ was calculated as $(nfarm - ave\,(nfarm))^2$, where $nfarm$ is the number of farms and $ave\,(nfarm)$ is the average over commodities and time.

7 Results and Discussion

Table 3 (below) shows the results of the estimations. Specification 1 includes only collective action variables; specification 2 adds variables controlling for geographical concentration and short-run income fluctuations; specification 3 allows for interaction effects and specification 4 controls for cross-commodity linkages.

In line with earlier studies (discussed in Section 4), the collective-action variables appear to have affected CAP support, which decreases with the number of farms and increases with size-heterogeneity. Specifications 1 and 3 find a negative linear relationship between the number of farms and support, whereas specifications 2 and 4 find a nonlinear relationship, yet negative within the sample. Gardner (1987) finds an inverse-U-shaped relationship between the number of farms and support, contradicting this result and the collective-action predictions.[7] However, Gardner's results may combine a variety of policy-mechanisms. Politicians favour large groups because of their voting power (Pincus, 1972; Lindbeck, 1985), so the inverted-U relationship could result from this voting-power effect (better with large numbers) counteracting the collective-action effect (better with small numbers). But the voting-power explanation is not equally applicable to the CAP, since supranational EU decision-making is more detached from voter influence. The results here confirm this.

The estimated coefficients for specification 2 indicate that, all else equal, a decrease in the number of farms by 10 000 would increase the support level by 0.16 percentage points (0.35% at the mean of the data). Olper (1998) investigates the effect of the number of farms on support aggregated over commodities in single EU member-states during 1975-1989 and finds that, in the average EU state, a decrease in the number of farms by 10 000 increased support by 0.03 - 0.06 Euro per unit of output.[8]

The estimated coefficients for size-heterogeneity (and squared) in specification 2 mean that if the standard deviation of the distribution increases by one unit, support would increase by 0.19 percentage points (or 0.41% at the mean

[7] Gardner's results suggest that there is "an optimal industry size" with respect to the effectiveness of lobbying (25000-150000 farms), different from collective-action theory.

[8] As dependent variable Olper uses the "nominal protection rate" (NPR), normalized by output, which does not include the effects of decoupled income transfers as here. However, such transfers became a substantial part of CAP support only after 1992.

Table 3. Effects of collective-action variables on CAP support, 1986-2003

Variable	(1)	(2)	(3)	(4)
number of farms	-0.008	-0.016	-0.020	-0.015
	(-1.83)	(-2.02)	(-2.49)	(-1.87)
squared number of farms	-5x10^{-7}	6x10^{-6}	5x10^{-6}	7x10^{-6}
	(-0.27)	(1.87)	(1.54)	(2.35)
size-heterogeneity	0.163	0.187	0.09	0.136
	(2.66)	(3.13)	(1.15)	(2.29)
squared size-heterogeneity	-0.002	-0.002	-0.002	-0.002
	(-2.68)	(-2.69)	(-2.81)	(-2.79)
geographical concentration		358.0	383.4	473.8
		(3.99)	(4.35)	(5.09)
lagged relative market price		-0.021	-0.02	-0.006
		(-5.01)	(-4.85)	(-0.97)
lagged output/producer		-308.45	-333.50	-239.8
		(-4.23)	(-4.53)	(-3.07)
(n. farms)*(size-het.)			9x10^{-8}	
			(1.70)	
CAP expenditures				-0.014
				(-0.68)
sum. number of farms				0.004
				(2.85)
sum. size-heterogeneity				-0.045
				(-2.64)
sum. geographical con.				98.01
				(3.01)
lagged sum. relative m. price				3.46
				(2.02)
lagged sum. output/producer				1833.8
				(3.15)
R^2 adjusted	0.17	0.34	0.34	0.29
F/χ^2, listed variables	51.43	6.38	6.25	43.34
F/χ^2, quadratic variables	5.24	4.29	4.27	5.00
F, cross-commodity var.				2.66
F/χ^2, commodity fixed effects		47.58	39.33	44.87
F/χ^2, time fixed effects	64.70	2.54	2.64	6.33
Time effects	Yes	Yes	Yes	No[a]
Hausman	1.00	15.60	17.82	29.84
Wald (group. heterosked.)[b]	761.22	50.44	52.63	42.02
Durbin-Watson (serial corr.)[c]	0.64	0.93	0.94	1.01

Student t-values are shown in parentheses
[a]Exclusion of time-specific effects are due to problems of multicollinearity (see below)
[b]Based on Greene (2003)
[c]As modified by Bhargava et al. (1982)

of the data). Using aggregate U.S. data, Bombardini (2005) also finds a positive effect.[9] The squared term here indicates that the positive effect diminishes with size, however. The interaction effect between the collective-action variables *number of farms* and *size-heterogeneity* (specification 3) is found to be statistically significant (on the ten percent level) and positive, though quite small. The intuition is that, as the number of farms increases, greater size-heterogeneity means more large farms, yielding more contributions (which is in accordance with the theory of collective action).[10] However, with this interaction effect allowed, the coefficient of size-heterogeneity is found not to be statistically significant.

Adjusted R^2 is 0.17 in specification 1 and jumps to 0.34 when the short-term income indicators and interaction effects are added, which is in line with earlier studies. The statistically significant effects of relative market price and output per producer suggest that policymakers consider the variability in agricultural income when deciding CAP support. When controlling for cross-commodity effects the adjusted R^2 increases to 0.43.

The geographical concentration of agricultural production within the EU has a statistically significant effect on support in all specifications, suggesting that a more geographically concentrated agricultural production leads to more efficient lobbying. The intuition is that the more geographically concentrated the industry, other things equal, the lower will be the cost of organizing effective lobbying.

All cross-commodity effects are statistically significant (specification 4). Note, however, that the model was estimated without time specific effects. This is because the full specification, including cross-commodity variables and time-specific effects, led to severe multicollinearity problems. In order to avoid (part of) the effect of multicollinearity the time specific effects were excluded, despite their significant effect as indicated by the F-test in Table 3. Hence, the results from this model should be interpreted with caution, as it is restricted both by

[9] American firms are required to report lobbying expenditures, which enables the researcher to test hypothesis on micro data. Bombardini thus tests the hypothesis empirically on firm-level data, finding that the amount of political action committee (PAC) contributions by each firm increases with size.

[10] Note that this interpretation presupposes a given industry size. However, the control for industry size, measured as the mean of the distribution economic size per commodity (see Appendix and the measurement of size-heterogeneity for a description of this measure), was found to be insignificant in all regressions and, therefore, excluded from the final regressions.

the summation of cross-commodity variables and the exclusion of time-specific effects (restrictions which are all imposed to avoid multicollinearity).

The number of farms producing other commodities has a positive effect. One interpretation is that the less effective the lobbying for support to other commodities, other things equal, the more support (out of a given budget) will be available to commodity i. If farms producing other commodities increased by 10 000, support to commodity i increased by 0.14 percentage points. Size-heterogeneity of other commodities has a negative effect. Again, this is in line with the theory of collective-action. The estimated coefficients for the other cross-commodity variables can be given a similar interpretation. However, the cross-commodity effect of geographical concentration takes the opposite sign to what was expected; the more concentrated the production of other commodities, the higher is the support for commodity i. Finally, the effect of total CAP expenditures is not statistically significant, though positive.[11]

8 Summary and Conclusions

When analyzing the influence of interest-group lobbying on the CAP, one must recognize that farmers in the EU as a whole are affected, so that there is an EU-wide collective-action problem. Thus the influence of lobbying groups with an EU-wide member-base - so called "Euro-Groups" - is studied using data from 1986-2003. In accordance with predictions from collective-action theory, the number of farms producing a given commodity and their size-heterogeneity are found to explain part of the variation in support for that commodity. This suggests that Euro-group lobbying has been able to influence the CAP. To some extent the results diverge from what is found in other studies, particularly on American data, perhaps because of the relatively lower direct influence of voters on agricultural policy in the EU.

More research is needed to more precisely identify the mechanisms of influence on the CAP, such as the interactions between EU-wide and national lobbying groups. Many policies determined at the national level (e.g., VAT taxes)

[11] The treatment of CAP expenditures is a difficult practical problem, since CAP expenditures are *compulsory*, which means that support-levels are set first, then total expenditures are determined (Ackrill, 2000, p. 79). As a result, CAP expenditures might be endogenous, not exogenous as assumed here.

have a considerable impact on the food industry, and thus may attract attention of national agricultural lobbying groups. The problem for the individual firm of how to allocate its lobbying expenditures between national and EU-wide levels is thus an issue for further scrutiny. The interaction between interest groups competing for the same resource would also bear further research. The test for cross-commodity linkages in the present study could be extended. However, the lack of firm-level data on lobbying contributions in the EU is a major obstacle to this research.

Appendix

Table A. Description of variables and data sources[a]

Variable	Description	Data source
estimated support	Monetary support in percent of total revenues	OECD
number of farms	Thousands of farms producing commodity i	Eurostat
size-heterogeneity	Standard deviation of the distribution of farms' standard gross margin[b]	Eurostat, own calc.
geographical concentration	Herfindahl index of geographical concentration[c]	Eurostat, own calc.
relative market price	$\frac{\text{world market-price of commodity } i \text{ (Euro)}}{\text{EU-level CPI}}$	OECD
output per producer	Commodity output in 1000 tonnes per farmer	Eurostat
CAP expenditures	Annual CAP expenditures (Euro). Deflated with EU-level CPI (1995=100)	OECD
sum. number of farms	Sum of number of farms for commodities $k \neq i$	Eurostat
sum. size-heterogeneity	Sum of size-heterogeneity for commodities $k \neq i$	Eurostat
sum. geo. concentration	Sum of geographical concentration for commodities $k \neq i$	Eurostat
sum. relative market price	Sum of relative market-price for commodities $k \neq i$	Eurostat
sum. output/producer	Sum of output per producer for commodities $k \neq i$	Eurostat

[a]Data include producer support estimates, prices, output, economic size distributions and the number of farms producing the commodities. The number of producers and output are based on survey data, available for the years 1987, 1990, 1993, 1995, 1997, 2000, and 2003. Following Gardner (1987) these data were interpolated between the years of the surveys.

[b]The standard gross margin is defined by Eurostat (2003) and is calculated as the value from one hectare or one animal, less the cost of variable input to produce that output. The data is the divided into nine economic size units (ESU) categories. The standard deviation of the size distribution of farms by category is then calculated. Because largest ESU is open-ended, a distributional assumption had to be made. Based on de Wit (2005), the ESU distribution is assumed to be log-normal. Class-limits are deflated using EU-level CPI (1995=100).

[c]Each member state of the EU is divided into regions, based on population. The Herfindahl index for commodity i in period t is then for m regions ($j = 1, ..., m$) calculated as (in the case of crops): $\sum_j \left(acre_{ijt} / \sum_j acre_{ijt}\right)^2$

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II

Market Power Effects of Supply Control and Dairy Market Deregulation

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Abstract

This paper uses the Bresnahan-Lau framework to analyze whether policy reforms specifically affecting Swedish dairy cooperatives, i.e. the two-price system (an input quota, 1986-1991) and the general deregulation of dairy policy (1991-1994), had any market power effects on the Swedish butter market. It is hypothesized that the two-price system enhanced market power, while the deregulation, making exports of butter less profitable, led to a lower level of market power exercised by dairy cooperatives. To account for non-stationary variables, a dynamic error correction model is adopted. The results show that the null hypotheses of no market power effect, for either of the two reforms, cannot be rejected at any reasonable significance level.

Keywords: agricultural policy, cooperatives, market power

JEL Classification: Q11, Q18, L22, L51, L66.

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1 Introduction

It is well known that marketing cooperatives are ill suited to exercise market power. The key reasons are fundamental. First, most marketing cooperatives' output levels are determined by the levels of production chosen by their members. Second, membership in such cooperatives is voluntary, and seldom does any single cooperative control the complete supply of a product. However, if the cooperative is able to restrict supply, a dominant market position is apt to weaken competition.[1] A cooperative may exercise market power either directly through quotas imposed on the members of the cooperative or via price discrimination.

The purpose of this paper is to test for changes in market power on the Swedish market for butter due to two specific policy reforms; the imposition of a raw milk supply quota - referred to as the "two-price system" - and a deregulation of export subsidies. The dataset contains monthly data and spans the period of January 1980 to December 1994. The two-price system was operative between January 1986 and June 1991, whereas between July 1991 and December 1994 dairy policy was deregulated and export subsidies were adjusted for the Swedish EU accession. The two-price system and the deregulation affected the farmers and their processing cooperatives, but not the retail industry (at least not directly). It is hypothesized that the two-price system enhanced the market power exercised by Swedish dairy cooperatives, while deregulation of export subsidies led to diminished market power. By controlling input supply, Swedish dairy cooperatives (marketing cooperatives with dominant regional market positions and owned by individual farmers with open membership) may have been able to exercise market power.[2] Lowered export subsidies due to the dairy market deregulation, on the other hand, may have reduced the possibilities of anticompetitive pricing on the domestic market, since price discrimination may have proved less profitable.

By focusing on the policy reforms and possible changes in market power due to these reforms, I will be able to circumvent one problem with the measurement of cooperative market power in the Swedish dairy market chain; namely, that only retail price and quantity data are available for processed dairy prod-

[1] See Sexton and Lavoie (2001) for an overview of the literature on cooperatives and competition.

[2] See SOU 1995:117 for a general description of the Swedish dairy market structure.

ucts. More specifically, assuming that the degree of market power exercised by retailers has been constant over the period, significant changes in market power occurring between the two intervals 1986-1991 and 1991-1994 will be tested for by estimating period specific effects, interpretable as reflecting the potential market power exercised by dairy cooperatives.

There exists a vast literature on the extent of imperfect competition in the food industry.[3] However, for dairy products, there are only a limited number of studies. Gohin and Guyomard (2000) consider the French dairy retail industry and they strongly reject the hypothesis that French food retail firms behave competitively. Similarly, Madhavan et al. (1994) find evidence of market power exercised by American dairy cooperatives in monopoly positions. According to their results, the dairy cooperatives discriminate between the markets for processed milk products, since the price elasticity of demand differs between the different submarkets. For the Swedish market, on the other hand, discriminatory pricing among domestic markets for processed dairy products may be limited, since own price elasticity estimates for different product groups are of the same magnitude.[4]

Turning to Swedish studies, Hedberg (2002) measures the extent of imperfect competition in the Swedish dairy industry in 1990. By using a mathematical programming model, she finds that observed consumer prices in 1990 are close to modelled competitive prices, indicating that no market power was exercised in the Swedish dairy market. In the present paper, I revisit the problem studied by Hedberg, but from another modelling perspective and with a wider time span. Moreover, I focus on the market for butter, for which a number of possible arguments for changes in market power over time exists (see below), making the test of market power easier. Another study which attempts to test for market power in the context of agricultural products - yet from a different perspective than Hedberg - is Bergman (1997), who estimates the effect of export volumes on domestic prices of agricultural products in seven OECD countries (including Sweden). Bergman finds that the domestic prices of agricultural products are positively correlated with exports, suggesting that there is price discrimination between domestic and foreign consumers. In this paper, I will be

[3] See e.g. Sheldon and Sperling (2003) for an overview of the literature.

[4] Hedberg (2002) reports the following own price elasticities of demand for dairy products in Sweden: fluid milk -0.40, milk powder -0.40, butter -0.45 and cheese -0.48.

able to assess the market power exercised by Swedish dairy cooperatives, due to (among other things) price discriminatory behavior, by building on a rigorous empirical approach to be described below.

Since the late 1980's, it has been common to use structural econometric models drawing on an approach referred to as the "new empirical industrial organization". This paper adopts this modelling paradigm and, more specifically, the methodology developed by Bresnahan-Lau (BL) (Bresnahan, 1982 and Lau, 1982). The BL method measures the conjectural variation elasticity at the industry level, which can be interpreted as the average of the individual firm's conjectural variation elasticities. The latter is a measure of all firms' output response to a price change relative to a change in the individual supplier's output, as conjectured by this individual supplier. Moreover, the approach allows for the identification of market power using aggregated time series industry data.

The paper is organized as follows. The next section describes the two-price system, and the dairy market deregulation and discusses how these reforms may have influenced the ability to exercise market power for Swedish dairy cooperatives. Section 3 presents the BL method. The empirical specification is presented in Section 4, and Section 5 presents and discusses the results. Finally, Section 6 summarizes and draws conclusions.

2 The Two-Price System and the 1991 Dairy Market Deregulation

The Swedish government started to systematically regulate the agricultural sector during the depression in the 1930s. To protect the farming population from falling prices and international competition, the domestic agricultural market was protected with duties and quantitative import regulations. These measures were coupled with regulated prices, where the domestic excess production, created by a price higher than the market-clearing price, was exported to the world market with the help of export subsidies. The subsidized dairy product was butter which, due to the methods for conservation, was the preferred commodity to export. The prices of processed dairy products (i.e. fluid milk, cream, butter and cheese) were determined in negotiations between representatives for the consumers and the farmers.[5] This system of internal regulation was officially institutionalized by the Swedish Parliament in 1947 and remained effective until 1991, when the Parliament majority decided to reform and deregulate major parts of the policy. At the same time Sweden applied for membership of the European Community (which later became the European Union (EU)). Sweden became a full member of the EU in 1995 and adopted the regulations of the Common Agricultural Policy (CAP).

In 1991 the decision to dismantle the dairy regulatory system became effective. However, once Sweden applied for EU membership, the deregulatory measures were replaced by a policy of adjusting existing regulations to the CAP structure. This nevertheless required the prices in the Swedish dairy market to be cut, since the prices of dairy products within the EU were significantly lower. The lower domestic prices were accompanied by a lowering of import duties and export subsidies; an adjustment to inner market liberalization in the EU. In 1995, the Swedish dairy market adopted the EU dairy policy.

Until the adoption of the CAP dairy policy in 1995, the Swedish dairy market was regulated via the price regulatory regime described above. However, during the period 1986-1991, an attempt was also made to directly restrict supply of raw milk through a voluntary quota construction, referred to as the two-price system. Launched in 1986, based on a parliamentary decision, the two-price system prescribed an individual quota to each farmer participating within the program (SHS, 1985). The name, "two-price system", refers to the two prices the individual farmer met when making his/her production decisions; a relatively high price for milk produced within the quota limit and a relatively low price for milk delivered to the dairy in excess of the quota. The system ended and the quotas were abolished in 1991. The two-price system was voluntary, meaning that it was optional for the dairy farmer to sign a contract to produce within the quota limits.[6]

Considering the effects of the policy reforms on the market power exercised by Swedish dairy cooperatives on the domestic butter market, the two-price system is hypothesized to have enhanced market power and the deregulation

[5] The consumers were represented by labor union representatives in this negotiation process (SOU 1995:117).

[6] See SOU 1995:117 for details on the 1991 deregulation of dairy policy in Sweden. To my knowledge, there is no information about the extent to which farmers participated in the program.

is hypothesized to have reduced market power. I will provide the intuition for these hypotheses that are grounded on Helmberger and Hoos (1962) and Bergman (1997). Helmberger and Hoos model a cooperative firm structure, given that open membership applies, and show that unless supply is restricted the cooperative will act as a perfect competitor. Bergman shows, building on the Helmberger and Hoos model, that price discrimination on a foreign market, where the cooperative is a price taker, may lead to a price higher than marginal cost in the domestic market, where the cooperative has a dominant market position.

- *Effect of the two-price system.* When a marketing cooperative's output level is determined via uncoordinated production decisions made by the members (as was most likely the case when the two-price system was not in operation), the cooperative is likely to behave as a perfect competitor. Thus, even if farmers collectively have market power through their cooperative, the market power will not be exercised if each farmer makes production decisions independently of others (since the farmers themselves are perfect competitiors to one another). The two-price system was an attempt to directly control farmer supply (presumably to a level below the competitive outcome). Hence, if the two-price system was effective, it may have led to *enhanced market power* for the Swedish dairy cooperatives over the period of January 1986 to June 1991.

- *Effect of the 1991 deregulation.* Another way to enhance the market power exercised by a marketing cooperative is through price discrimination. Price discrimination is profitable, in principle, whenever a firm faces multiple selling markets, demand elasticities differ across markets, and the markets are segmented in the sense that resales from low-price to high-price markets can be prevented. A dairy cooperative may increase profits relative to the competitive outcome by restricting butter sales on the domestic market (where demand faced by the cooperative was relatively inelastic) and consequently dumping butter in the market where the cooperative faces a more elastic demand (i.e. the world market). The 1991 deregulation of Swedish dairy policy led to significantly lower export subsidies on butter and possibly also a weaker bargaining position for the dairy farmers when the prices of processed dairy products were determined. Hence, we might expect a *negative market power effect* for Swedish dairy cooperatives over the period of January 1991 to December 1994.

In Table 1, the time-intervals considered in this study are listed together with the period-specific policy reforms and their hypothesized market power effects.

Table 1. Time invervals and policy reforms

Period	Time interval	Policy reform	Market power effect
1	January 1980 - December 1985		
2	January 1986 - June 1991	Two price system	(+)
3	July 1991 - December 1994	Deregulation	(-)

3 The Bresnahan-Lau Model

The test for market power is done based on the Bresnahan-Lau method. Consider a static model. The market demand function for butter is given by

$$Q_D = Q_D\left(P, Z; \alpha\right) \tag{1}$$

where Q_D is the quantity demanded, P the price, Z a vector of demand side shift variables and α a vector of parameters to be estimated. The aggregate supply relation for butter can be written as

$$P = c\left(Q_S, W; \beta\right) \tag{2}$$

in which Q_S is the quantity supplied, W a vector of shift variables and β a vector of parameters to be estimated. Marginal cost is given by $c\left(\cdot\right)$. However, when firms are not price takers, the perceived marginal revenue, not price, will be equal to marginal cost. In this case, we may rewrite the supply relation as

$$P = c\left(Q_S, W; \beta\right) - \lambda h\left(Q_D, Z; \alpha\right) \tag{3}$$

where $P + h\left(\cdot\right)$ is marginal revenue at the industry level. Thus $h\left(\cdot\right)$ is the semi-elasticity of market demand, $Q_D / \left(\partial Q_D / \partial P\right)$, and λ is now a measure of market power. When $\lambda = 1$ we have a perfect cartel (given that $h\left(\cdot\right) < 0$), and when $\lambda = 0$ we have perfect competition.

The practical problem is to identify λ. Bresnahan (1982) solved this problem by supplementing the shift variables in the demand function with rotation variables. This is done by adding PZ to the explanatory variables in equation (1).

To see how λ is identified, assume that both demand and marginal cost are linear, and that the equilibrium quantity (where the marginal revenue is equal to the marginal cost) is given by, $Q = Q_D = Q_S$. Equation (1) can then be written

$$Q = \alpha_0 + \alpha_P P + \alpha_Z Z + \alpha_{PZ} PZ \tag{4}$$

and if the marginal cost is given by $\beta_0 + \beta_Q Q + \beta_W W$, the supply relation in equation (3) may be written

$$P = \beta_0 + \beta_Q Q + \beta_W W - \lambda \left[\frac{Q}{\alpha_P + \alpha_{PZ} Z} \right] \tag{5}$$

since marginal revenue of the industry equals $P + [Q/(\alpha_P + \alpha_{PZ} Z)]$. Given estimates of α_P and α_{PZ}, λ is now identified. Also, for later use, define $Q^* = -Q/(\alpha_P + \alpha_{PZ} Z)$. The formal effect of including the rotation variable, PZ, in the demand equation is that the demand function is not separable in Z. Lau (1982) shows that identification is possible as long as this is true, regardless of functional form.

The BL method has been subject to criticism (see e.g. Corts, 1999). However, Clay and Troesken (2003) and Genesove and Mullin (1998) have shown that the method performs well as long as the degree of market power is not too high. Therefore, given that the Swedish dairy market consisted (over the period of measurement) of cooperatives owned by more than 20 000 dairy farmers, I will assume that the BL method is appropriate to use.

4 The Empirical Specification

The product of interest is Swedish butter. The data consists of monthly observations, and the full estimation period is January 1980 to December 1994. In total, the dataset consists of 180 observations. The shift variable in the demand function, Z, is income. As the study is based on aggregate data for Sweden as a whole, income is measured as the Gross Domestic Product (GDP). The vector W in the supply function is represented by two cost measures: $W1$, a total cost index for farmers (including the costs for requisites, services and capital costs) and $W2$, a labor cost index for the food processing industry.[7]

To capture the possibility that the degree of market power has changed over time (in accordance with the hypotheses discussed above), I have constructed two time dummy variables. The first dummy variable, $D1$, takes the value one for the time period when the two-price system was operating, January 1986 until June 1991, and zero otherwise. The second dummy variable, $D2$, is equal to one for the period when Swedish dairy policy was being deregulated, from July 1991 until December 1994, and is zero otherwise. By multiplying each dummy variable with the market power variable, Q^*, two market power interaction variables are constructed, $D1Q^*$ and $D2Q^*$, in order to test for significant changes in market power due to the dairy specific reforms. The estimated parameter for Q^* measures market power exercised on the Swedish butter market over the period January 1980 - December 1985; the joint effect of Q^* and $D1Q^*$ measures market power exercised between January 1986 and June 1991, and the joint effect of Q^* and $D2Q^*$ reflects market power exercised between July 1991 and December 1994. Hence, the estimated parameters of $D1Q^*$ and $D2Q^*$ in the regressions below measure the market power effect of the two-price system and the dairy policy deregulation, respectively, given that the market power exercised by retailers has been constant over the estimation period as a whole. Summary statistics are given in Table 2 (see Appendix A for a precise description of the dataset and the variable definitions).

Table 2. Summary statistics

Variable[a]	Unit	Mean	Std. dev.	Min.	Max
quantity of butter (Q)	tons	3359	889.4	1712	5980
price of butter (P)	SEK/kg	48.48	6.12	35.24	58.14
income (Z)	10k SEK	4061	380.2	3271	4852
total cost ($W1$)	index	2.54	0.123	2.24	2.73
labor cost ($W2$)	index	1.03	0.051	0.94	1.13

[a]The monetary variables, i.e. P, Z, $W1$ and $W2$, are deflated using the Swedish Consumer Price Index

The theoretical background and the BL method are based on a static formulation. Hence, I start by specifying a static empirical model, based on equations

[7]The price of raw milk was tested as an explanatory variable in the supply regression, without any significant contribution to the model.

(4) and (5). It is written

$$Q_t = \alpha_0 + \alpha_P P_t + \alpha_Z Z_t + \alpha_{PZ} (PZ)_t + \varepsilon_t \tag{6}$$

$$\begin{aligned} P_t &= \beta_0 + \beta_Q Q_t + \beta_{W1} (W1)_t + \beta_{W2} (W2)_t + \lambda_1 Q_t^* \\ &\quad + \lambda_2 (D1Q^*)_t + \lambda_3 (D2Q^*)_t + \eta_t \end{aligned} \tag{7}$$

where ε_t and η_t are error terms.

Since time series data are used to test the null hypothesis of no market power, non-stationarity among the variables might pose a problem, which is the reason why Steen and Salvanes (1999) propose a dynamic reformulation of the BL model using an error correction model (ECM) framework.[8] Such a model solves the inference problem that may arise if non-stationary time-series data are applied to equation (6) and (7), since the variables in the ECM specification are either stationary due to differentiation or represent cointegrating relations. The ECM formulation also allows for short-run deviations from the long-run equilibrium of the data. Such deviations may be caused by factors such as random shocks, sticky prices and contracts. By including lagged observations of the dependent variables, the ECM framework also incorporates dynamic factors such as habit formation on the demand side and adjustment costs for producers. The general dynamic demand ECM can be written:

$$\begin{aligned} \Delta Q_t &= \overline{\alpha}_0 + \sum_{i=1}^{d} \overline{\alpha}_{Q,i} \Delta Q_{t-i} + \sum_{i=1}^{f} \overline{\alpha}_{P,i} \Delta P_{t-i} + \sum_{i=1}^{g} \overline{\alpha}_{Z,i} \Delta Z_{t-i} \\ &\quad + \sum_{i=1}^{h} \overline{\alpha}_{PZ,i} \Delta (PZ)_{t-i} + \widehat{\alpha}_{Q,k} Q_{t-k} + \widehat{\alpha}_{P,k} P_{t-k} \\ &\quad + \widehat{\alpha}_{Z,k} Z_{t-k} + \widehat{\alpha}_{PZ,k} (PZ)_{t-k} + \epsilon_t \end{aligned} \tag{8}$$

where ϵ_t is an error term, the prefix Δ is the difference operator, and the lag lengths d, f, g, h and k are to be determined by the data. The long-run demand

[8] Apart from the study by Steen and Salvanes, which addresses market power on the French salmon market exercised by Norwegian producers, a dynamic reformulation of the BL method has also been applied by Roberts and Samuelson (1988), analyzing the U.S. cigarette market; Bask et al. (2007) and Hjalmarsson (2000), addressing imperfect competition in the Nordic power market, and Durevall (2004), measuring market power in the Swedish coffee market.

parameters are then calculated according to

$$\theta_j = -\frac{\widehat{\alpha}_{j,k}}{\widehat{\alpha}_{Q,k}}, \qquad j = P, Z, PZ$$

The general dynamic supply ECM is given by

$$\begin{aligned}
\Delta P_t &= \overline{\beta}_0 + \sum_{i=1}^{l} \overline{\beta}_{P,i} \Delta P_{t-i} + \sum_{i=1}^{m} \overline{\beta}_{Q,i} \Delta Q_{t-i} + \sum_{i=1}^{n} \overline{\beta}_{W1,i} \Delta (W1)_{t-i} \\
&+ \sum_{i=1}^{p} \overline{\beta}_{W2,i} \Delta (W2)_{t-i} + \sum_{i=1}^{q} \overline{\lambda}_{1,i} \Delta Q^*_{t-i} + \sum_{i=1}^{r} \overline{\lambda}_{2,i} \Delta (D1Q^*)_{t-i} \\
&+ \sum_{i=1}^{s} \overline{\lambda}_{3,i} \Delta (D2Q^*)_{t-i} + \widehat{\beta}_{P,v} P_{t-v} + \widehat{\beta}_{Q,v} Q_{t-v} + \widehat{\beta}_{W1,v} (W1)_{t-v} \\
&+ \widehat{\beta}_{W2,v} (W2)_{t-v} + \widehat{\lambda}_{1,v} Q^*_{t-v} + \widehat{\lambda}_{2,v} (D1Q^*)_{t-v} + \widehat{\lambda}_{3,v} (D2Q^*)_{t-v} \\
&+ \varpi_t
\end{aligned} \tag{9}$$

where $Q^*_t = -Q_t / (\theta_P + \theta_{PZ} Z_t)$, ϖ_t is an error term, and the lag lengths l, m, n, p, q, r, s and v are to be determined by the data. The long run supply parameters are given by

$$\xi_j = -\frac{\widehat{\beta}_{j,v}}{\widehat{\beta}_{P,v}} \qquad j = Q, W1, W2.$$

$$\Lambda_j = -\frac{\widehat{\lambda}_{j,v}}{\widehat{\beta}_{P,v}} \qquad j = 1, 2, 3.$$

Hence, Λ_1, Λ_2 and Λ_3 are measures of market power in the long run.[9]

5 Results and Discussion

According to the stationarity test reported in the Appendix B, all variables are generated by non-stationary processes, but are stationary in first difference. However, the static model, as given by equations (6) and (7), only contains

[9] Equations (8) and (9) are written as factorized ECMs, i.e. as they are estimated. See e.g. Bårdsen (1989) for a derivation of these equations from an Auto Distributed Lag model and how it corresponds to a non-factorized ECM. Bårdsen also shows how the variance of the long-run estimates are calculated.

non-stationary variables.[10] This means that the static model may give rise to spurious regression results. Therefore, and since the static model also exhibits autocorrelation, I will focus on the dynamic model. For completeness, the results of the static model are reported in the Appendix D.

In order to test for existence of long-run solutions in the dynamic model, cointegration tests are performed. As reported in Appendix B, I find clear indications of cointegration in both the demand and supply functions.

I start by presenting the results for the dynamic demand function (equation (8)) in Table 3. Here I only report the parameter estimates associated with the level variables and the corresponding long-run effects. The estimated effects of the variables in difference, i.e. the short-run effects, are presented in the Appendix C. All parameters parameter estimates corresponding to the level variables are found to be statistically significant at least at the 10% level. The long-run price elasticity is found by calculating $\phi_P = [\theta_P + \theta_{PZ} Z]\,[P/Q]$ and the long-run income elasticity is calculated according to $\phi_Z = [\theta_Z + \theta_{PZ} P]\,[Z/Q]$. Evaluated at the mean of the data, the point estimate of the long-run price elasticity is -0.38, which suggests an inelastic demand curve, and the point estimate of the long-run income elasticity is equal to -0.05. The price elasticity estimate is in line with earlier literature, but the estimate of the income elasticity is smaller. For instance, Edgerton et al. (1996) use micro-data to estimate the own-price and income elasticity for fat and oils in Sweden, finding an own-price elasticity of -0.3 and an income elasticity of 0.5. However, the elasticities estimated in this paper are not statistically significant at any reasonable level and should, therefore, be interpreted with caution.[11]

The estimate of the adjustment parameter, $\widehat{\alpha}_{Q,1}$, is equal to -0.195, indicating an adjustment of 19.5% per month after deviation from the long-run

[10] An alternative approach would be to apply equations (6) and (7) to variables differentiated to the order in which they are stationary; one does not need to incorporate dynamics or cointegrating level variables just because the variables are non-stationary. Moreover, such a specification would be more in line with the original BL method, compared with the dynamic ECM formulation proposed here. However, I have estimated such a model, in which all parameter estimates turned out to be insignificant. This may indicate that both the long-run information, provided by the level variables, and the short-run dynamic information, provided by the lagged differentiated variables, contribute significantly to the data generating process.

[11] The standard deviation of the price elasticity estimate is 0.51, whereas the corresponding standard deviation for the income elasticity is 0.57.

Table 3. Estimates of the dynamic demand function (8)[a,b]

	Parameter[c]	Std. dev.
$\widehat{\alpha}_{Q,1}$	-0.195***	0.044
$\widehat{\alpha}_{P,1}$	-198.6*	106.85
$\widehat{\alpha}_{Z,1}$	-2.32*	1.24
$\widehat{\alpha}_{PZ,1}$	0.047*	0.025
θ_P	-1017*	584.1
θ_Z	-11.87*	6.78
θ_{PZ}	0.244*	0.138
R^2 adjusted	0.64	
Q(1)	0.011	
Q(6)	2.72	
Q(12)	9.29	
Q(36)	36.75	

[a]The estimated parameters for the differenced terms in (8) can be found in Table C in Appendix C.

[b]The lag for the level variables is based on the results in Appendix C.

[c]The asterisks ***,** and * denote significance at the 1, 5 and 10 percent levels.

equilibrium. The adjusted R^2 is equal to 0.64, and there is no autocorrelation, according to the Ljung-Box Q statistics. Moreover, as seen in Table 3, the null of $\theta_{PZ} = 0$ can be rejected at the 10% level of significance. The latter will be interpreted to mean that the demand function is not separable in Z, so I can use the effect of PZ to identify market power parameters.

Turning to the estimated dynamic supply function, the results are presented in Table 4. There are no significant effects of market power.[12] Hence, the hypothesis of no market power cannot be rejected. The adjusted R^2 is equal to 0.24, and no autocorrelation is found according to the Ljung-Box Q statistics. One statistically significant long run effect is found; total costs have a positive effect on the price of butter.

[12]Since this lack of significance may be due to the relatively low level of significance of the effect of the rotation variable, PZ, in the demand function, I tested to estimate butter demand using a different rotation variable. A model with the price of margarine (a substitute good) and the price of margarine times the price of butter included as shift variables in the demand function was estimated (with and without Z and PZ included). However, no significant market power was detected.

Table 4. Estimates of the dynamic supply function (9)[a,b]

	Parameter[c]	Std. dev.
$\widehat{\beta}_{P,3}$	-0.073**	0.035
$\widehat{\beta}_{Q,3}$	0.00004	0.0001
$\widehat{\beta}_{W1,3}$	3.67*	2.14
$\widehat{\beta}_{W2,3}$	3.45	3.82
$\widehat{\lambda}_{1,3}$	0.0052	0.021
$\widehat{\lambda}_{2,3}$	-0.0050	0.021
$\widehat{\lambda}_{3,3}$	-0.0076	0.021
ξ_Q	0.00052	0.0019
ξ_{W1}	50.67***	14.65
ξ_{W2}	47.59	49.06
Λ_1	0.071	0.303
Λ_2	-0.069	0.303
Λ_3	-0.105	0.315
R^2 adjusted	0.24	
Q(1)	0.179	
Q(6)	4.55	
Q(12)	7.46	
Q(36)	38.11	

[a]The estimated parameters for the differenced terms in (9) can be found in Table C in Appendix C.

[b]The lag for the level variables is based on the derivation found in Appendix C.

[c]The asterisks ***,** and * denote significance at the 1, 5 and 10 percent levels.

One possible explanation for these results is that the bargaining power of the farmer community, when the prices of processed dairy products were determined, was not strong enough to generate prices significantly above marginal costs. This argument is also in line with Hedberg (2002), who finds that the prices of processed dairy products in 1990 were close to competitive prices. Furthermore, the insignificant effect of the two-price system may be due to an ineffective quota rule; for instance, if a significant number of farmers decided not to participate.[13] Finally, market power on the domestic butter market may have been difficult to uphold for the dairy cooperatives due to competition from

[13]According to the dairy farmer industry organisation, large scale milk producers may have benefitted from not producing within the quota limits (SHS 1985 p 6).

substitute goods; e.g. margarine. Since margarine is made of vegetable oils, producers of oilseeds might press the butter price down to competitive levels. However, as reported, the price of margarine did not produce any significant effect on the demand for butter; a significant effect would have been expected if price competition between margarine and butter existed during the period of study.[14]

6 Summary and Conclusions

The effects of the two-price system and the 1991 deregulation of dairy policy on the market power exercised by Swedish dairy cooperatives on the butter market is analyzed in a Bresnahan-Lau framework. In order to distinguish the market power exercised by cooperatives from that exercised by retailers, changes in dairy regulations are accounted for using interaction variables. The results of a dynamic ECM show no significant effects of market power for any of the reforms considered. This is in accordance with Hedberg (2002), who finds that prices of dairy products (including butter) were at competitive levels in 1990.

Possible explanations for the lack of significant market power effects are that the farmers held a weak bargaining position (relative to the consumer representatives) when the prices of dairy products were decided upon; that the quota rule are inefficient, or that the butter price was affected by competition from substitute goods.

Food markets are still subject to heavy regulations. In Sweden, the CAP is now the regulatory regime deciding the conditions for farmers and processing firms. More research is needed to assess the ability of food producers to exercise market power within such a context. Moreover, from a national perspective, the inner market of the EU and the free mobility of goods have changed the environment for Swedish farmers and market cooperatives and, thus, their ability to exercise market power. This is a problem worthy of further scrutiny.

[14] Since the price of butter is highly correlated with the price of margarine, this lack of significance may be due to multicollinearity.

Appendix A: Data Description

Table A. Description of variables and data sources

Variable[a]	Description	Data source[b]
price of butter[c] (P)	Retail prices of butter per kg in Sweden	JEM
quantity of butter (Q)	Butter produced for the Swedish market	JEM
income[d] (Z)	Gross Domestic Product	SS
total cost ($W1$)	Aggregated index measure of weighted costs for agricultural production including requisities (fuel and lubricants, fertilizers, fodder and electricity), services (freights, milk control, insemination costs, machine hire) and capital costs (interest costs and depreciation of machines, tools and buildings). Base year: 1980	JEM
labour cost ($W2$)	Labour cost index for the food processing industry. Base year: 1991	SS

[a] All monetary variables, the price of butter, total cost index and income are deflated using the Swedish Consumer Price Index (all-item) (Statistics Sweden).
[b] JEM: Jordbruksekonomiska meddelanden, published by the Swedish Agricultural Market Board, SS: Statistics Sweden
[c] Observations are missing for the price of butter for the year 1990 (12 observations). The missing observations are predicted using the Swedish Consumer Food Price Index (Statistics Sweden).
[d] The income variable, Z, is reported quarterly and the missing observations are interpolated linearly.

Appendix B: Stationarity and Cointegration Tests

The stationarity of each variable is tested using the Augmented Dickey-Fuller unit root test (Dickey and Fuller, 1979). The null hypothesis is that the variable contains a unit root, and the alternative is that the variable is generated by a stationary process. I have used the Akaike Information Criterion (AIC) to determine the number of lags. The results are reported in Table B1.

To ensure the existence of a long-run solution, the multivariate cointegration test of Johansen and Juselius (Johansen, 1988; Johansen and Juselius, 1990) is undertaken. The test is a likelihood ratio test on the result given from a vector autoregressive model. The null hypothesis of the trace statistic is that there are no more than r cointegrating relations. Steen and Salvanes (1999) provide an thorough description of the multivariate cointegration test. The test, as reported in Table B2, indicates one cointegrating vector for the demand function and four cointegrating relations in the supply function.

Table B1. Augmented Dickey-Fuller Unit Root Tests[a]

Variable	$I\,(0)$	Lag	$I\,(1)$	Lag
price of butter (P)	-0.148 (0.944)	3	-9.810 (0.000)	2
quantity of butter (Q)	-2.227 (0.196)	14	-3.520 (0.007)	13
income (Z)	-1.151 (0.694)	4	-6.818 (0.000)	3
price*income (PZ)	-1.401 (0.582)	4	-8.293 (0.000)	3
total cost index ($W1$)	0.558 (0.986)	3	-9.613 (0.000)	2
labour cost index ($W2$)	-1.831 (0.365)	1	-12.461 (0.000)	0

[a]MacKinnon (1994) approximate P-value within parentheses

Table B2. Cointegration tests

Demand function: Q, P, PZ, Z (4 lags)		
	Trace statistic	5% critical value
1 cointegration vector ($r = 0$)	63.10	47.21
2 cointegration vectors ($r = 1$)	22.95	29.68
3 cointegration vectors ($r = 2$)	10.27	15.41
4 cointegration vectors ($r = 3$)	0.51	3.76
Supply function: $P, Q, W1, W2, Q^*, D1Q^*, D2Q^*$ (2 lags)		
	Trace statistic	5% critical value
1 cointegration vector ($r = 0$)	269.06	124.24
2 cointegration vectors ($r = 1$)	180.99	94.15
3 cointegration vectors ($r = 2$)	110.40	68.52
4 cointegration vectors ($r = 3$)	51.07	47.21
5 cointegration vectors ($r = 4$)	28.44	29.68
6 cointegrating vectors ($r = 5$)	8.33	15.41
7 cointegrating vectors ($r = 6$)	0.046	3.76

Appendix C: Derivation of the Dynamic Model

In order to determine the appropriate formulation of the dynamic model the following test procedure is undertaken:

1. The lag length for the variables in levels, i.e. k in the demand equation, and v in the supply equation, is determined by regressing the level variables on the dependent variable, testing fourteen specifications, i.e $k = 1, ..., 14$ and $v = 1, ..., 14$. I have decided to test fourteen specifications based on the Schwertz (1989) criterion, $L_{\max} = [12 \times (T/100)^{0.25}]$, where T is equal to the number of observations and $L = k, v$. With the number of observations in the data sample equal to 180, this criterion yields an estimate of 13.89. The Bayesian Information Criterion (BIC) is used as the criterion determining which of the fourteen alternatives that is appropriate.

2. Models regressing the dependent variable with respect to the differenced variables with a total of 14 lags (using the Schwertz criterion) are estimated. The variables with the least significant parameter are excluded, one-by-one, until the best model (according to the BIC) is reached.

3. Given the lag specification for each differenced variable in 2. and the lag structure determined for the level variables in 1., a model with all variables is estimated. The differenced variables with the least significant parameter estimates are excluded one-by-one, until minimum BIC was reached.

The estimated effects of the differenced variables are listed in Table C.

Table C. Estimates of the differenced terms of equations (8) and (9)

	Parameter[a]	Std. dev.
$\overline{\alpha}_0$	10329*	5279
$\overline{\alpha}_{Q,1}$	-0.268***	0.070
$\overline{\alpha}_{Q,12}$	0.457***	0.064
$\overline{\alpha}_{Q,13}$	-0.362***	0.066
$\overline{\alpha}_{PZ,6}$	0.014**	0.005
$\overline{\alpha}_{Z,9}$	-1.51***	0.485
$\overline{\beta}_0$	-9.53	6.63
$\overline{\beta}_{P,1}$	-0.396***	0.073
$\overline{\beta}_{P,2}$	-0.283***	0.074
$\overline{\beta}_{P,12}$	0.258***	0.070
$\overline{\beta}_{Q,10}$	0.0004**	0.0001

[a]The asterisks ***,** and * denote significance at the 1, 5 and 10 percent levels

Appendix D: Estimates of the Static Model

First, equation (6) is estimated. Then, after using the estimates of the parameters α_P and α_{PZ} to calculate Q^*, $D1Q^*$ and $D2Q^*$, the supply relation in equation in equation (7) is estimated. To account for the simultaneity problem, equations (6) and (7) are estimated with two stage least squares (2SLS), using the exogenous variables of the supply function as instuments in the demand function, and vice versa. In the demand, P and PZ; and in the supply relation, Q, Q^*, $D1Q^*$ and $D2Q^*$, are assumed to be (potentially) endogenous. Using the Hansen J validity test for the instruments, I cannot reject the null of validity in both models. The results of these test and the estimated coefficients are reported in Table D.

Table D. Estimates of the static demand and supply functions, (6) and (7)

Demand	Parameter[a]	Std. dev.
α_0	65526*	34828
α_P	-1217.2*	720.38
α_Z	-14.52*	8.25
α_{PZ}	0.299*	0.171
R^2 adjusted/Hansen J	0.92/0.00	
Q(1)[b]/Q(6)	84.82***/114.87***	
Q(12)/Q(36)	264.13***/604.11***	

Supply	Parameter[a]	Std. dev.
β_0	-438.5***	80.28
β_Q	-0.035***	0.009
β_{W1}	142.1***	25.09
β_{W2}	237.0***	44.91
λ_1	-0.0002***	$4\text{x}10^{-5}$
λ_2	0.008**	0.003
λ_3	0.002***	$5\text{x}10^{-4}$
R^2 adjusted/Hansen J	0.66/0.00	
Q(1)/Q(6)	103.55***/253.92***	
Q(12)/Q(36)	332.20***/379.58***	

[a] The asterisks ***,** and * denote significance at the 1, 5 and 10 percent levels
[b] Ljung-Box Q test, lag lenght within paratheses

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III

International Environmental Policy Reforms, Tax Distortions, and the Labor Market

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This paper concerns the welfare consequences of environmental policy cooperation in a two-country economy. We assume that the countries finance their public expenditures by using distortionary taxes, and that they differ with respect to competition in the labor market. The purpose is to characterize the welfare effect of a policy reform, where the countries agree to slightly increase their expenditures on abatement. We show how the welfare effect of the policy reform depends on changes in the environmental damage, employment, and work hours. We also relate the welfare effect to the strategic interaction among the countries in the prereform equilibrium.

Keywords: policy cooperation, distortionary taxes, labor market, Nash game, Stackelberg game

JEL classification: H 41, J 51, J 60

1. Introduction

Transboundary environmental problems imply that the emissions generated by each country do not only give rise to deterioration of the domestic environment; they also affect the environment facing the residents in other countries. To deal with such resource allocation problems, it has been recognized that some kind of cooperation is typically required. However, the notion of cooperation does not necessarily mean that countries pool their resources in order to implement a cooperative equilibrium concept. It is more realistic to assume that they agree upon smaller projects, the purposes of which are to improve the resource allocation. This paper analyzes the welfare consequences of such an agreement between countries to increase their expenditures on environmental (abatement) policy. The purpose is to derive and characterize the resulting welfare change measure. Contrary to most earlier studies dealing with transboundary environmental problems, we pay explicit attention to how preexisting tax distortions and imperfect competi-

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tion in the labor market contribute to the welfare effect of environmental policy coordination. We also relate the welfare effect of policy coordination to the strategic interaction among countries in the prereform equilibrium – an issue that has not yet been thoroughly addressed.

There is a large literature dealing with different aspects of environmental policy. The methodological discussions may concern a variety of issues such as the valuation of nonmarket goods, equity, uncertainty, and the evolution of the ecosystem[1]. During the last decade, a number of studies have also emerged, where fiscal and labor-market distortions operate simultaneously with environmental externalities. The basic argument is, of course, that market economies are typically characterized by a number of distortions, each of which may influence the welfare effects of projects aimed at improving the environment[2]. However, earlier research on economic policy, where environmental damage and other distortions jointly affect the policy outcome, typically abstracts from international spillover effects of environmental damage[3]. This is somewhat surprising, since transboundary environmental problems play a major role in the debate surrounding practical policy. As a consequence, it is important to broaden the theoretical framework for studying environmental policy. Our paper aims at doing that by combining earlier literature on environmental policy under preexisting tax distortions and labor-market imperfections[4], respectively, with the study of transboundary environmental problems. To simplify the presentation, we use a model economy comprising two countries.

Why is it interesting to extend the study of environmental policy reform along the lines indicated above? First, with transboundary environmental damage it follows that the tax and expenditure policies of a particular country generally affect the behavior and welfare in other countries as well,

1 See e.g., Pindyck (2000) and Tol (2001). See also the introductory text by Hanley (2000) and the references therein.

2 This idea has been recognized and elaborated on in the literature on environmental taxes and/or environmental tax reforms in the presence of other tax distortions; see, e.g., Bovenberg and de Mooij (1994), Bovenberg and Goulder (1996), Parry et al. (1999), and Aronsson (1999).

3 An exception is Hoel (1997), who considers environmental policy in combination with imperfect competition in the labor market. The basic issue in his study is whether international environmental targets should be supplemented by coordination of the policies used to implement these targets. Another exception is Aronsson and Blomquist (2003), who consider redistribution and environmental policy in a two-country model, where each national government faces a mixed tax problem. See also the literature on optimal environmental tax differentiation, e.g., Felder and Schleiniger (2000).

4 Previous studies on environmental policy reforms under imperfect competition in the labor market are typically based on one-country model economies, in which transboundary environmental problems do not arise; see, e.g., Schneider (1997), Bovenberg and van der Ploeg (1998), and Koskela and Schöb (1999).

suggesting that the welfare effects associated with the fiscal system are more complex in economies with transboundary environmental problems than in the models typically used in earlier literature. Second, real-world labor markets differ substantially across countries with regards to the degree of competition. For instance, European labor markets are typically characterized by union wage formation, which causes involuntary unemployment at the equilibrium, whereas the labor market in the U.S. bears more resemblance to a competitive market. Since unemployment is a major social problem in many countries, the labor market is likely to play an important role in the choice of economic policy (including environmental policy) at the national level. This will be exemplified by assuming that one of the countries is characterized by union wage formation, while the labor market in the other country is competitive. Third, as we indicated above, the welfare effects of a policy reform designed to impose some degree of coordination among countries also depend on how the countries solve their resource allocation problems prior to the reform; for instance, whether the countries act in a way similar to Nash competitors, or whether a particular country acts as a first mover. Earlier literature often assumes that the alternative to cooperation is a noncooperative Nash equilibrium[5], which, therefore, represents the reference case with which the welfare effects of cooperation ought to be compared. Although this assumption may have intuitive appeal, it is not necessarily appropriate, as countries differ considerably in size and strength.

We shall not explicitly address the conditions under which coalitions are likely to form. Our main purpose is, instead, to study the national and global welfare consequences that would arise *if* the countries were to agree to slightly increase their expenditures on abatement. The paper contributes to the literature primarily in two ways. The first is by characterizing the resulting welfare change measure. Our paper generalizes the study of environmental policy by simultaneously addressing (1) imperfect competition in the labor market, (2) distortionary taxation, (3) endogenous hours of work, (4) policy reform, and (5) transboundary external effects. The second is to emphasize how the welfare change measure depends on the policies carried out in each country prior to the reform as well as on the strategic interaction between the countries. We discuss three alternative scenarios. First, we derive a general cost–benefit rule that does not necessarily require that the public policy be optimally chosen on a national basis prior to the reform. This rule always applies as long as each national government fulfills its budget constraint. Second, we consider a situation where the prereform equilibrium is a noncooperative Nash equilibrium, implying that each national government has made an optimal policy choice conditional on the private and public decision

5 See, e.g., Barrett (1994), Carraro and Siniscalco (1993), and Tahvonen (1994).

variables in the other country. Finally, we derive the welfare effects of policy cooperation under the assumption that the prereform equilibrium is the outcome of a Stackelberg game. This provides an interesting alternative to the Nash game, in that differences in size and strength among countries are likely to influence their strategic behavior. To our knowledge, there are no previous studies on environmental policy reforms at the global level where a Stackelberg game governs the initial resource allocation.

The analysis will be carried out in a general-equilibrium model, where each country faces a utilitarian social welfare function. In section 2, we present the model and analyze the outcome of private optimization. Furthermore, in line with much earlier research on the welfare effects of public policy, we assume that the private sector in each country solves its optimization problem conditional on the policy variables, whereas the policymakers recognize how the private agents respond to policy. The main results are presented in section 3. A simplifying assumption here is that labor is immobile between the countries[6]. This does not reflect a belief that labor mobility is unimportant; only that many of its consequences for environmental policy are well understood from earlier research on international (or interregional) spillover effects and factor mobility[7]. Thus, this also enables us to focus on how tax and labor-market distortions interact with transboundary externalities in the context of policy reforms, as our assumptions imply that the international spillover effects of environmental damage constitute the only *direct* interaction between the countries. Section 4 contains a summary and discussion of the results.

2. The Model

2.1. Consumers and Firms

The economy consists of two countries, which are denoted by subindex $i = 1, 2$, and there are M_i immobile residents in country i. The only important structural difference between the countries refers to the labor market: the wage formation process in country 1 is assumed to be influenced by trade unions, whereas the labor market in country 2 is competitive.

6 Labor mobility is discussed in an earlier version of the paper, which is available from the authors upon request. We show that labor mobility is compatible with the main line of reasoning in the paper and is not of main importance for the qualitative results. In our framework, labor mobility primarily affects the way in which employment-related motives behind public policy enter the welfare change measure, not the presence of such motives *per se*.

7 See, e.g., Wellisch (1995), Sandmo and Wildasin (1999), and Aronsson and Blomquist (2003).

The consumers share a common utility function, $u_i = u(c_i, z_i, x)$, where c_i is private consumption and z_i leisure, while $x = (x_1, x_2)$ is a vector whose elements are the environmental damages generated by the two countries. We assume that the utility is increasing in c_i and z_i, decreasing in x, and strictly quasiconcave. We also require that the consumers treat x as exogenous. The environmental damage generated by country i, x_i, is assumed to increase with the use of energy in the production in country i, g_i, and decrease with the use of public expenditures on abatement in country i, α_i:

$$x_i = \rho_i\big(g_i, \alpha_i\big), \tag{1}$$

where the assumptions made above imply $\partial\rho_i/\partial g_i > 0$ and $\partial\rho_i/\partial\alpha_i < 0$.

The budget constraint of an employed consumer is given by $c_i^e = w_i l_i(1 - \tau_i)$, where w_i is the wage rate, l_i the hours of work, and τ_i the labor income tax rate. The superindex e stands for "employed". By using $z^i = T - l^i$, where T is a time endowment, the first-order condition for the hours of work is given by

$$\frac{\partial u_i^e}{\partial c_i^e} w_i\big(1 - \tau_i\big) - \frac{\partial u_i^e}{\partial z_i} = 0, \tag{2}$$

where $u_i^e = u(c_i^e, z_i, x)$. Equation (2) implicitly defines the labor supply, $l_i = l(w_i, \tau_i, x)$.

Unemployment is a possibility only for consumers in country 1. The budget constraint for an unemployed individual is given by $c_1^u = b_1$, where b_1 is a fixed unemployment benefit, and the utility becomes $u_1^u = u(b_1, T, x)$. The superindex u stands for "unemployed".

The production side of the economy in each country is competitive and consists of identical competitive firms producing a homogeneous good. The variable factors of production are labor and energy. By disregarding entry into, and exit out of, the goods market in each country, the number of firms in each country is fixed and will be normalized to one. The objective function facing the firm in country i is written

$$\Pi_i = f(L_i, g_i) - w_i L_i - t_i g_i, \tag{3}$$

where L_i represents the total employment, measured as the hours of work per employee, l_i, times the number of employed persons, N_i, whereas g_i is the energy input and t_i the energy tax. In country 2, there is no unemployment, so $N_2 = M_2$. The production function $f(\cdot)$ is increasing in each argument and strictly concave, and we assume that the firms treat w_i and t_i as exogenous. The first-order conditions are

$$\frac{\partial f(\cdot)}{\partial L_i} - w_i = 0, \tag{4}$$

$$\frac{\partial f(\cdot)}{\partial g_i} - t_i = 0 \tag{5}$$

for $i = 1, 2$, which implicitly define the labor demand function $L_i = L(w_i, t_i)$ and the energy demand function $g_i = g(w_i, t_i)$, which satisfy $\partial L_i/\partial w_i < 0$ and $\partial g_i/\partial t_i < 0$. For later use, it will be convenient to define the labor demand in country 1 in terms of the number of employed persons:

$$N_1 = \tilde{N}\left(w_1, l_1, t_1\right) = \frac{L(w_1, t_1)}{l_1}. \tag{6}$$

The supply of energy is assumed to be infinitely elastic, and the marginal cost of producing energy is set to zero. This simplification is not important for the qualitative results.

In accordance with some earlier work[8] on optimal taxation under imperfect competition in the labor market, we assume that the pure profits accrue to the government. An alternative would have been to distribute the profits among the consumers (and possibly incorporate profit income taxation). This choice is not important for the qualitative results derived below. Each national government uses the revenues from the labor income tax, the energy tax, and the profits to finance the expenditures on abatement[9]. In country 1, part of the tax revenues is also used to finance the unemployment benefits. The budget constraint facing the government in country 1 is written

$$\tau_1 w_1 N_1 l_1 + t_1 g_1 + \Pi_1 - (M_1 - N_1) b_1 - \alpha_1 = 0, \tag{7}$$

while the budget constraint for the government in country 2 is given by

$$\tau_2 w_2 M_2 l_2 + t_2 g_2 + \Pi_2 - \alpha_2 = 0, \tag{8}$$

where α_1 and α_2 represent the resources spent on abatement. For later use, note that by combining the government's budget constraint, the private budget constraints, and the objective function of the firm in each country, we can derive the resource constraints

$$f(N_1 l_1, g_1) - N_1 c_1^e - \left(M_1 - N_1\right) c_1^u - \alpha_1 = 0, \tag{9}$$

$$f(M_2 l_2, g_2) - M_2 c_2^e - \alpha_2 = 0, \tag{10}$$

implying that output is used for private and public consumption.

2.2. The Labor Market in Country 1

In this subsection, we address wage formation in country 1, where the influence of trade unions gives rise to unemployment. We assume that all

8 See, e.g., Fuest and Huber (1999) and Koskela and Schöb (2002).

9 A possible extension is to introduce expenditures on other public goods, which may affect utility, production, or both. Such extensions do not affect the results derived below, as long as the provision of public goods is not used explicitly for balancing the national budget constraints during policy coordination.

workers are union members, and that wage formation is decentralized. The latter is interpreted to mean that each union is small relative to the economy as a whole, and that each union treats the policy instruments of the government as exogenous. This is consistent with earlier work on optimal taxation under imperfect competition in the labor market, as it enables us to formulate the national policy problems in subsections 3.2 and 3.3 as if the government were the first mover *vis-à-vis* the private sector (including the unions).

To save notational space, we will not go into technical detail about the wage formation process. For the analysis to be carried out below, it suffices to assume that the equilibrium wage rate,

$$w_1 = w_1(\tau_1, t_1, b_1, x), \tag{11}$$

exceeds the market-clearing wage rate, meaning that there is unemployment at the equilibrium. Then, by substituting the wage equation into the labor demand function, we obtain an equation for the number of employed persons:

$$N_1 = \tilde{N}(w_1(\tau_1, t_1, b_1, x), l_1, t_1) = N(\tau_1, t_1, l_1, b_1, x) < M_1. \tag{12}$$

3. Cost–Benefit Rules for Abatement

In section 2, we addressed the optimization problems of the private sector. This meant characterizing the outcome of the private decision problems conditional on the public policy and the environmental damage. Here, we combine the outcome of private optimization with different assumptions about the behavior of the national governments in order to derive cost–benefit rules for policy reforms that are associated with the use of abatement.

3.1. A General Cost–Benefit Rule

A cost–benefit rule for environmental policy cooperation is dependent on how each national government behaves prior to the reform. To begin with, we shall not assume that each national government has made an optimal policy choice prior to the reform; only that each national government fulfills its budget constraint. This means that the cost–benefit rule considered here is general in the sense that it applies to any preexisting level of each policy instrument, as long as (7) and (8) apply.

By using the first-order conditions for the consumer and the firm in each country, the wage equation, the vector $x = (x_1, x_2)$ and $x_i = \rho_i(g_i, \alpha_i)$ for $i = 1, 2$, we can solve for l_1, w_1, g_1, N_1, l_2, w_2, and g_2 as functions of τ_1, τ_2, t_1,

t_2, b_1, α_1, and α_2:

$$l_i = \hat{l}_i(\tau_1, t_1, \tau_2, t_2, b_1, \alpha_1, \alpha_2),$$
$$w_i = \hat{w}_i(\tau_1, t_1, \tau_2, t_2, b_1, \alpha_1, \alpha_2),$$
$$g_i = \hat{g}_i(\tau_1, t_1, \tau_2, t_2, b_1, \alpha_1, \alpha_2),$$
$$N_1 = \hat{N}_1(\tau_1, t_1, \tau_2, t_2, b_1, \alpha_1, \alpha_2).$$

Here, we shall assume that the energy tax in each country is adjusted as a response to the policy reform in order to balance the budget of the government. By substituting the behavioral equations above into the budget constraints of the national governments, we can solve for t_1 and t_2 as functions of the other policy variables. Then, by substituting back into the behavioral equations, we obtain

$$\begin{aligned} l_i &= \overline{l}_i(\tau_1, \tau_2, b_1, \alpha_1, \alpha_2),\\ w_i &= \overline{w}_i(\tau_1, \tau_2, b_1, \alpha_1, \alpha_2),\\ g_i &= \overline{g}_i(\tau_1, \tau_2, b_1, \alpha_1, \alpha_2),\\ N_1 &= \overline{N}_1(\tau_1, \tau_2, b_1, \alpha_1, \alpha_2) \end{aligned} \tag{13}$$

for $i = 1, 2$, in which we have used that t_1 and t_2 are endogenous. Finally, by using (1) and (13), we can solve for x_1 and x_2, respectively, as functions of τ_1, τ_2, b_1, α_1, and α_2.

In previous studies on optimal taxation and provision of public goods under imperfect competition in the labor market, such as Fuest and Huber (1997) and Aronsson and Sjögren (2004), a utilitarian social welfare function (or an extension thereof) is used. We will follow this approach by assuming that each national government faces a utilitarian social welfare function. The social welfare function of country 1 is written

$$W_1 = N_1 u_1^e + \left(M_1 - N_1\right) u_1^u, \tag{14}$$

and the corresponding social welfare function for country 2 is given by

$$W_2 = M_2 u_2^e. \tag{15}$$

In this framework, it is natural to assume that also cooperation is governed by a utilitarian welfare function

$$W = W_1 + W_2, \tag{16}$$

meaning that the cost–benefit rule we are looking for can be written as

$$dW = \frac{\partial W}{\partial \alpha_1} d\alpha_1 + \frac{\partial W}{\partial \alpha_2} d\alpha_2. \tag{17}$$

Let us begin by considering the derivative of (16) with respect to α_1. Differentiating (9), (10), and (16) with respect to α_1, while using the private budget constraints and the equations (13), we obtain

Proposition 1 Within the given framework, the cost benefit rule for α_1 can be written as

$$\frac{\partial W}{\partial \alpha_1} = \sum_{i=1}^{2}\left[N_1\frac{\partial u_1^e}{\partial x_i} + (M_1 - N_1)\frac{\partial u_1^u}{\partial x_i} + M_2\frac{\partial u_2^e}{\partial x_i}\right]\frac{\partial x_i}{\partial \alpha_1} - \frac{\partial u_1^e}{\partial c_1^e}$$
$$+ \frac{\partial u_1^e}{\partial c_1^e}\left[\tau_1 w_1 N_1\frac{\partial l_1}{\partial \alpha_1} + t_1\frac{\partial g_1}{\partial \alpha_1}\right] + \frac{\partial u_2^e}{\partial c_2^e}\left[\tau_2 w_2 M_2\frac{\partial l_2}{\partial \alpha_1} + t_2\frac{\partial g_2}{\partial \alpha_1}\right]$$
$$+ \frac{\partial N_1}{\partial \alpha_1}\left[(u_1^e - u_1^u) + \frac{\partial u_1^e}{\partial c_1^e}(w_1 l_1 \tau_1 + b_1)\right].$$

Proof. See the appendix.

Proposition 1 decomposes the welfare effect of an increase in α_1 into three parts, each of which is represented by one of the lines in the formula. To begin with, consider the sum in the first line. If this sum is positive, it is interpretable in terms of the direct marginal benefit of reducing the environmental damage, which is measured by the sum of the marginal utilities of environmental damage times the change in the environmental damage following the increase in α_1. Note that, although an increase in α_1 is likely to reduce x_1 (both directly, and indirectly via the higher energy tax), the influence of α_1 on x_2 is nevertheless ambiguous. As a consequence, without additional assumptions, we cannot rule out that an increase in α_1 leads to more environmental damage measured in terms of the joint influence on x_1 and x_2, though that outcome seems unlikely. The second part of the first line, $\partial u_1^e/\partial c_1^e$, reflects the direct marginal cost associated with the additional resources spent on abatement in country 1. Note that goods are measured in such a way that increased abatement expenditures reduce the expenditures on private consumption by the same amount for a given output. This explains why the direct marginal cost of abatement is measured by the marginal utility of consumption[10]. In the absence of distortions other than environmental damage, the first line would represent the full cost–benefit rule for α_1.

The welfare effects via the preexisting tax system, measured conditional on the number of employed persons, are represented by the second line. The preexisting tax distortions influence welfare, because an increase (a decrease) in the tax base makes it less (more) costly to finance public expenditures. To be more specific, the preexisting taxes on labor income and energy affect the cost–benefit rule for abatement via the effects of α_1 on work hours and energy use, respectively, and an increase in the expenditures on abatement

10 Since unemployment gives rise to heterogeneity, employed and unemployed individuals differ with respect to the marginal utility of consumption. Alternatively, we could have written the cost–benefit rule so that the direct marginal cost of abatement is interpretable in terms of the marginal utility of consumption of the unemployed.

may either increase or decrease the preexisting tax distortions. Note also that, since the utility functions are not necessarily separable in environmental damage, it follows that both x_1 and x_2 generally affect the private decision variables in both countries. This means, in turn, that α_1 does not only affect the private decision variables in country 1; it also affects the private decision variables in country 2.

The third line measures the welfare effect of an increase in the number of employed persons in country 1. Higher employment increases welfare for two reasons: (1) there is a private utility gain of being employed instead of unemployed (provided that $u_1^e > u_1^u$), and (2) the tax revenues net of transfer payments increase, implying that it becomes less costly to finance public consumption. Therefore, if the number of employed persons increases (decreases) in response to higher abatement spending, there is an additional welfare gain (loss) associated with policy coordination for the unionized economy.

Note finally that the only differences to this rule, had we increased the level of abatement in country 2 instead of in country 1, would refer to the direct marginal cost of abatement, i.e., that $\partial u_1^e/\partial c_1^e$ must be replaced by $\partial u_2^e/\partial c_2^e$, and to the fact that α_1 must be replaced by α_2. This means that the cost–benefit rule for α_2 takes the same general form, and is interpretable in the same general way, as the cost–benefit rule for α_1 above, implying that there is no need to derive the cost–benefit rule for α_2 in order to be able to interpret the results.

3.2. Noncooperative Nash Game

So far, we have made no assumptions about how each national government has chosen its policy prior to cooperation. This means that the cost–benefit rule analyzed in the previous subsection is valid for any preexisting policy, provided that the national governments fulfill their budget constraints. However, as we mentioned in the introduction, previous studies on international environmental policy often assume that the alternative to cooperation is a noncooperative Nash equilibrium. It is therefore interesting to examine the implications of policy coordination in the context of the noncooperative Nash equilibrium. In addition, this prereform equilibrium concept is intuitively reasonable in that it presupposes that each national government (and not just the private sector) has made an optimal policy choice (from its own perspective) prior to policy cooperation, and that no individual country is strong enough to act as a first mover. To some extent, this may represent the environmental policy cooperation within the European Union (provided, of course, that the national governments behave as if they solve domestic optimal tax and expenditure problems prior to such cooperation).

Therefore, suppose that each national government (prior to policy co-operation) chooses its policy variables in an optimal way by maximizing its own objective function subject to its resource constraint, while treating the private and public decision variables of the other country as exogenous. For country 1, we can use the first-order conditions for the private sector together with $x_1 = \rho_1(g_1, \alpha_1)$ to define

$$l_1 = l_1(\tau_1, t_1, b_1, \alpha_1, x_2), \tag{18}$$

$$w_1 = w_1(\tau_1, t_1, b_1, \alpha_1, x_2), \tag{19}$$

$$N_1 = N_1(\tau_1, t_1, b_1, \alpha_1, x_2), \tag{20}$$

$$g_1 = g_1(\tau_1, t_1, b_1, \alpha_1, x_2). \tag{21}$$

By using (18)–(21) together with the private budget constraints, i.e., $c_1^e = w_1 l_1(1 - \tau_1)$ and $c_1^u = b_1$, and the function that generates the environmental damage, $x_1 = \rho_1(g_1, \alpha_1)$, the prereform policy problem of country 1 will be to choose τ_1, t_1, b_1, and α_1 to maximize

$$\begin{aligned} \pounds_1 &= N_1 u\big(c_1^e, z_1, x\big) + [M_1 - N_1] u\big(c_1^u, T, x\big) \\ &\quad + \mu_1\big[f(N_1 l_1, g_1) - N_1 c_1^e - (M_1 - N_1) c_1^u - \alpha_1\big] \end{aligned} \tag{22}$$

while at the same time treating x_2 as exogenous. In (22), μ_1 is the Lagrange multiplier associated with the resource constraint. This procedure gives the optimal policy for country 1 as $\tau_1^* = \tau_1(x_2)$, $t_1^* = t_1(x_2)$, $b_1^* = b_1(x_2)$, and $\alpha_1^* = \alpha_1(x_2)$, where the asterisk indicates that the national government has made an optimal choice conditional on the private and public decision variables of the other country.

Similarly, using the first-order conditions for the private sector in country 2 together with $x_2 = \rho_2(g_2, \alpha_2)$, we have

$$l_2 = l_2(\tau_2, t_2, \alpha_2, x_1), \tag{23}$$

$$w_2 = w_2(\tau_2, t_2, \alpha_2, x_1), \tag{24}$$

$$g_2 = g_2(\tau_2, t_2, \alpha_2, x_1). \tag{25}$$

By using (23)–(25) together with the private budget constraint, i.e., $c_2^e = w_2 l_2(1 - \tau_2)$, and the function that generates the environmental damage, $x_2 = \rho_2(g_2, \alpha_2)$, the prereform policy problem of country 2 will be to choose τ_2, t_2, and α_2 to maximize

$$\pounds_2 = M_2 u\big(c_2^e, z_2, x\big) + \mu_2\big[f(M_2 l_2, g_2) - M_2 c_2^e - \alpha_2\big] \tag{26}$$

while at the same time treating x_1 as exogenous. The optimal policy for country 2 becomes $\tau_2^* = \tau_2(x_1)$, $t_2^* = t_2(x_1)$, and $\alpha_2^* = \alpha_2(x_1)$.

A Nash equilibrium is defined such that τ_1^*, t_1^*, b_1^*, and α_1^* represent the optimal fiscal policy choice of country 1 conditional on the assumption that τ_2^*, t_2^*, and α_2^* have been chosen by country 2 and vice versa. We assume here that the countries have reached this Nash equilibrium prior to any agreement on policy coordination.

Now, suppose that the countries agree to slightly increase their expenditures on abatement. More specifically, the abatement expenditures in country 1 are increased to $\alpha_1^* + \overline{\alpha}_1$ and the abatement expenditures in country 2 to $\alpha_2^* + \overline{\alpha}_2$, where $\overline{\alpha}_1$ and $\overline{\alpha}_2$ are small positive constants. As before, t_1 and t_2 are assumed to be adjusted in order to balance the budget constraints facing the national governments, whereas τ_1, τ_2, and b_1 are given by their prereform values. We may reformulate the energy tax functions to read $t_1^* = t_1(x_2, \overline{\alpha}_1)$ and $t_2^* = t_2(x_1, \overline{\alpha}_2)$, where the prereform resource allocation means that $\overline{\alpha}_1 = 0$ and $\overline{\alpha}_2 = 0$. Then, by using (21) and (25) together with $x_1 = \rho_1(g_1, \alpha_1)$ and $x_2 = \rho_2(g_2, \alpha_2)$, we can write x_1 and x_2 as functions of $\tau_1, t_1, b_1, \alpha_1, \tau_2, t_2$, and α_2:

$$x_1 = \phi_1(\tau_1^*, t_1^*, b_1^*, \alpha_1^* + \overline{\alpha}_1, \tau_2^*, t_2^*, \alpha_2^* + \overline{\alpha}_2), \tag{27}$$

$$x_2 = \phi_2(\tau_1^*, t_1^*, b_1^*, \alpha_1^* + \overline{\alpha}_1, \tau_2^*, t_2^*, \alpha_2^* + \overline{\alpha}_2). \tag{28}$$

The effects of changes in $\overline{\alpha}_1$ and $\overline{\alpha}_2$ on x_1 and x_2 can then be derived by using (27) and (28).

An important difference between the analysis to be carried out here and that of the previous subsection is that we here assume that each country has already made an optimal policy choice at the national level. As a consequence, some of the welfare effects that would otherwise arise from a policy reform will vanish as a consequence of optimization. To be able to address the welfare effects of policy coordination in a simple way, let us substitute the Nash equilibrium values of the policy variables into the Lagrangians, while using that $W_1 = £_1$ and $W_2 = £_2$ in the noncooperative Nash equilibrium. Since the noncooperative Nash equilibrium means that $\partial £_1/\partial \alpha_1 = 0$ and $\partial £_1/\partial t_1 = 0$ conditional on x_2, and $\partial £_2/\partial \alpha_2 = 0$ and $\partial £_2/\partial t_2 = 0$ conditional on x_1, whereas τ_1, b_1, and τ_2 are not affected by the reform (which we assumed above), it follows that

$$\frac{\partial £_1}{\partial \overline{\alpha}_1} = \frac{\partial £_1}{\partial x_2}\frac{\partial x_2}{\partial \overline{\alpha}_1}, \tag{29}$$

$$\frac{\partial £_2}{\partial \overline{\alpha}_1} = \frac{\partial £_2}{\partial x_1}\frac{\partial x_1}{\partial \overline{\alpha}_1}. \tag{30}$$

Similarly, the effects of $\overline{\alpha}_2$ are given by

$$\frac{\partial £_1}{\partial \overline{\alpha}_2} = \frac{\partial £_1}{\partial x_2}\frac{\partial x_2}{\partial \overline{\alpha}_2}, \tag{31}$$

$$\frac{\partial £_2}{\partial \overline{\alpha}_2} = \frac{\partial £_2}{\partial x_1}\frac{\partial x_1}{\partial \overline{\alpha}_2}, \tag{32}$$

where the derivatives of x_1 and x_2 with respect to $\overline{\alpha}_1$ and $\overline{\alpha}_2$, respectively, can be derived by using (27) and (28).

The cost–benefit rule is derived by differentiating the social welfare function in equation (16) with respect to $\overline{\alpha}_1$ and $\overline{\alpha}_2$, respectively, and evaluating the resulting derivatives at the noncooperative Nash equilibrium where $\overline{\alpha}_1 = 0$ and $\overline{\alpha}_2 = 0$. By combining (29), (30), (31), and (32), we have derived the following general result:

Proposition 2 If the prereform equilibrium is represented by the noncooperative Nash equilibrium, the cost–benefit rule for policy cooperation is given by

$$dW = \left[\frac{\partial £_1}{\partial x_2}\frac{\partial x_2}{\partial \overline{\alpha}_1} + \frac{\partial £_2}{\partial x_1}\frac{\partial x_1}{\partial \overline{\alpha}_1}\right] d\overline{\alpha}_1 + \left[\frac{\partial £_1}{\partial x_2}\frac{\partial x_2}{\partial \overline{\alpha}_2} + \frac{\partial £_2}{\partial x_1}\frac{\partial x_1}{\partial \overline{\alpha}_2}\right] d\overline{\alpha}_2.$$

To provide an interpretation of proposition 2, note first that $\overline{\alpha}_1$ and $\overline{\alpha}_2$ only affect country 1 via x_2 and country 2 via x_1. As we mentioned above, the reason is that the domestic welfare effects of abatement are internalized in the noncooperative Nash equilibrium. The transboundary parts of the external effects, on the other hand, are not internalized, implying that a policy reform at the global level affects welfare via the spillover effects of environmental damage. To see this more clearly, note that the derivatives $\partial £_1/\partial x_2$ and $\partial £_2/\partial x_1$, which are evaluated at the noncooperative Nash equilibrium, can be written as

$$\begin{aligned}\frac{\partial £_1}{\partial x_2} &= \frac{\partial N_1}{\partial x_2}\left[u_1^e - u_1^u\right] + N_1\left[\frac{\partial u_1^e}{\partial c_1^e}\frac{\partial w_1}{\partial x_2} l_1(1-\tau_1) + \frac{\partial u_1^e}{\partial x_2}\right] \\ &\quad + [M_1 - N_1]\frac{\partial u_1^u}{\partial x_2} \\ &\quad + \mu_1\left[w_1\left(\frac{\partial N_1}{\partial x_2} l_1 + N_1\frac{\partial l_1}{\partial x_2}\right) + f_g\frac{\partial g_1}{\partial x_2} - \frac{\partial N_1}{\partial x_2}\left(c_1^e - c_1^u\right) - N_1\frac{\partial c_1^e}{\partial x_2}\right],\end{aligned} \tag{33}$$

$$\begin{aligned}\frac{\partial £_2}{\partial x_1} &= M_2\left[\frac{\partial u_2^e}{\partial c_2^e}\frac{\partial w_2}{\partial x_1} l_2(1-\tau_2) + \frac{\partial u_2^e}{\partial x_1}\right] \\ &\quad + \mu_2\left[w_2 M_2\frac{\partial l_2}{\partial x_1} + f_g\frac{\partial g_2}{\partial x_1} - M_2\frac{\partial c_2^e}{\partial x_1}\right],\end{aligned} \tag{34}$$

in which we have used the private budget constraints and the first-order conditions for the hours of work. Equations (33) and (34) imply that x_2 (x_1) affects $£_1$ ($£_2$) via two channels: (1) a direct utility effect of the change in the environmental damage and (2) indirect effects via the private decision variables. The latter effects follow because we have not made any assumptions about separability in the utility function. Note also that x_2 affects the Lagrangian of country 1 in a different way from that in which x_1 affects the Lagrangian of country 2, since the two countries differ with respect to competition in the labor market.

The welfare effect of policy cooperation measured by proposition 2 can, in general, go in either direction. One reason is that (33) and (34) may be either positive or negative, since the indirect effects of the environmental damage on the private decision variables depend on the properties of the utility and production functions. In addition, although $\partial x_1/\partial\overline{\alpha}_1$ and $\partial x_2/\partial\overline{\alpha}_2$ are likely to be negative, we cannot determine the signs of the derivatives $\partial x_2/\partial\overline{\alpha}_1$ and $\partial x_1/\partial\overline{\alpha}_2$.

Although we are not able to determine whether the policy reform leads to higher or lower welfare in general, the basic message of proposition 2 is, nevertheless, of practical relevance for welfare measurement; it shows that *all* welfare effects of the reform are associated with transboundary spillover effects of environmental damage. This result is due to the assumption that each national government has made an optimal policy choice on a national basis prior to the reform. By comparison with the analysis in subsection 3.1, the main contribution here is that we are able to relate the welfare change measure to precise assumptions about the prereform resource allocation – an issue to be further discussed in subsection 3.3. To the extent that real-world market economies act as if they are Nash competitors to one another (which is an empirical question), proposition 2 also gives guidance for practical policy design by showing what information to look for.

The following result is a direct consequence of proposition 2:

Corollary 1 If the utility function takes the form $u_i = \tilde{u}(c_i, z_i) + \psi_{1i}(x_1) + \psi_{2i}(x_2)$, the cost–benefit rule for policy cooperation in proposition 2 reduces to

$$dW = M_2 \frac{\partial u_2^e}{\partial x_1} \frac{\partial x_1}{\partial \overline{\alpha}_1} d\overline{\alpha}_1 + \left[N_1 \frac{\partial u_1^e}{\partial x_2} + (M_1 - N_1) \frac{\partial u_1^u}{\partial x_2} \right] \frac{\partial x_2}{\partial \overline{\alpha}_2} d\overline{\alpha}_2,$$

implying that

$$dW > 0 \quad \text{if } \frac{\partial x_1}{\partial \overline{\alpha}_1} < 0 \text{ and } \frac{\partial x_2}{\partial \overline{\alpha}_2} < 0.$$

Corollary 1 implies that an agreement to slightly increase the expenditures on abatement influences country 1 via the direct effects of x_2 on u_1^e and u_1^u and influences country 2 via the direct effect of x_1 on u_2^e. The other welfare effects discussed in the context of proposition 2 vanish because the private decision variables no longer directly depend on the environmental damage, and because $\partial x_1/\partial\overline{\alpha}_2 = \partial x_2/\partial\overline{\alpha}_1 = 0$. This means that the cost–benefit rule takes the same general form as it would have taken in the absence of distortionary taxes and imperfect competition in the labor market: neither preexisting taxes nor employment effects are present in the formula in corollary 1[11].

11 A result similar to corollary 1 (although with a focus on policy coordination with respect to emission taxation) was derived by Aronsson and Löfgren (2000) in a framework without any distortions other than transboundary external effects from environmental damage.

3.3. Stackelberg Game

The rationale for studying policy coordination in the context of a Stackelberg game is, of course, that countries may differ considerably with regard to size and strength. For instance, consider a situation where a large country faces many small countries. In this case, the large country is more likely to be able to commit to its policies than any of the smaller countries, indicating that it is reasonable to treat the large country as the first mover. As such, the large country recognizes the reaction functions for the smaller countries and uses them in the context of its own optimization problem. Although it is unclear to what extent large countries actually act as if they are first movers, it may not be unreasonable to argue that the U.S. might have the ability to act as a first mover *vis-à-vis* some of its neighboring countries.

To simplify the analysis, with little loss of generality, we continue to concentrate on the two-country model[12]. We assume, to begin with, that the competitive economy, prior to any policy cooperation, acts as a leader in the sense of recognizing how the unionized economy reacts to its policy, whereas the unionized economy is follower. The latter means that the unionized economy acts as a Nash competitor in the same way as in the previous subsection. Now, the competitive economy recognizes the reaction functions, $\tau_1^* = \tau_1(x_2)$, $t_1^* = t_1(x_2)$, $b_1^* = b_1(x_2)$, and $\alpha_1^* = \alpha_1(x_2)$, and incorporates them into its optimization problem. By using these reaction functions together with $x_1 = \rho_1(g_1, \alpha_1)$ and $x_2 = \rho_2(g_2, \alpha_2)$, we can solve for x_1 as a function of τ_2, t_2, α_2, and $\overline{\alpha}_1$, i.e.,

$$x_1 = \check{x}_1(\tau_2, t_2, \alpha_2 + \overline{\alpha}_2, \overline{\alpha}_1).$$

Equations (23)–(25) can then be rewritten as follows:

$$l_2 = l_2\left(\tau_2, t_2, \alpha_2 + \overline{\alpha}_2, \check{x}_1(\tau_2, t_2, \alpha_2 + \overline{\alpha}_2, \overline{\alpha}_1)\right), \tag{35}$$

$$w_2 = w_2\left(\tau_2, t_2, \alpha_2 + \overline{\alpha}_2, \check{x}_1(\tau_2, t_2, \alpha_2 + \overline{\alpha}_2, \overline{\alpha}_1)\right), \tag{36}$$

$$g_2 = g_2\left(\tau_2, t_2, \alpha_2 + \overline{\alpha}_2, \check{x}_1(\tau_2, t_2, \alpha_2 + \overline{\alpha}_2, \overline{\alpha}_1)\right), \tag{37}$$

where $\overline{\alpha}_1 = 0$ and $\overline{\alpha}_2 = 0$ prior to the policy reform. The optimization problem facing the competitive economy prior to policy cooperation will be to choose τ_2, t_2 and α_2 to maximize

$$£_2 = M_2 u_2^e + \mu_2\left[f(M_2 l_2, g_2) - M_2 c_2^e - \alpha_2\right] \tag{38}$$

subject to (35)–(37) and $c_2^e = w_2 l_2(1 - \tau_2)$. The outcome of this policy problem is denoted τ_2^{**}, t_2^{**}, and α_2^{**}.

12 As pointed out to us by one of the referees, one way of justifying the Stackelberg game in this setting is to interpret the leader as being a large country that faces many small countries described as followers. Then, by normalizing the number of small countries to one, we obtain the framework discussed in this subsection.

Suppose that the economy has reached the equilibrium in the Stackelberg game, and consider the same policy reform as we carried out in the previous subsection. Note also that, since the competitive economy uses t_2 to balance its budget, it follows that the effect of $\overline{\alpha}_1$ on x_1 takes the form

$$\frac{\partial x_1}{\partial \overline{\alpha}_1} = \frac{\partial \check{x}_1}{\partial \overline{\alpha}_1} + \frac{\partial \check{x}_1}{\partial t_2}\frac{\partial t_2}{\partial \overline{\alpha}_1}$$

from the point of view of the competitive economy. All calculations for the unionized economy (the follower) are the same as in the previous subsection. Consider the following proposition:

Proposition 3 If the prereform equilibrium is represented by the outcome of a Stackelberg game where the competitive economy is leader and the unionized economy follower, the cost–benefit rule for policy cooperation is given by

$$dW = \left[\frac{\partial £_1}{\partial x_2}\frac{\partial x_2}{\partial \overline{\alpha}_1} + \frac{\partial £_2}{\partial x_1}\frac{\partial x_1}{\partial \overline{\alpha}_1}\right] d\overline{\alpha}_1 + \frac{\partial £_1}{\partial x_2}\frac{\partial x_2}{\partial \overline{\alpha}_2} d\overline{\alpha}_2.$$

In proposition 3, the derivatives $\partial £_1/\partial x_2$ and $\partial £_2/\partial x_1$ are given by (33) and (34). A comparison between propositions 2 and 3 implies that one of the derivatives that were present in proposition 2, $\partial £_2/\partial \overline{\alpha}_2$, is not part of the formula in proposition 3. The reason is, of course, that the Stackelberg leader has already internalized the effect of α_2 on x_1, meaning that $\partial £_2/\partial \overline{\alpha}_2 = 0$. The contribution to the cost–benefit rule by the leader only arises because α_2 affects the welfare of the follower. In other words, the part of the agreement that refers to actions undertaken by the leader does not give rise to any "domestic" welfare effects for the leader. Thus, if the environmental damage generated by the follower only has a minor effect on the welfare of the leader, then the leader may not have much to gain from policy cooperation. One possible interpretation is that, if the national government is able to commit to its policies, it might be more reluctant to participate in international environmental policy agreements than it would otherwise have been.

Clearly, the assumption that the competitive economy acts as leader is arbitrary. By performing analyses similar to those described above, one can show that the cost–benefit rule corresponding to the situation where the unionized economy is leader and the competitive economy follower will be symmetric to the one discussed in proposition 3:

$$dW = \frac{\partial £_2}{\partial x_1}\frac{\partial x_1}{\partial \overline{\alpha}_1} d\overline{\alpha}_1 + \left[\frac{\partial £_1}{\partial x_2}\frac{\partial x_2}{\partial \overline{\alpha}_2} + \frac{\partial £_2}{\partial x_1}\frac{\partial x_1}{\partial \overline{\alpha}_2}\right] d\overline{\alpha}_2.$$

Therefore, this change of assumption does not affect the basic insight behind proposition 3: the part of the agreement that refers to the behavior of the leader affects the global welfare only via the objective function of the follower.

4. Discussion

This paper concerns transboundary environmental problems in a framework with preexisting tax distortions and imperfect competition in the labor market, and the analysis is based on a general-equilibrium model of a two-country economy. The contribution is to characterize the cost–benefit rule associated with environmental policy cooperation. Thus, the paper provides an understanding of the mechanisms that determine the welfare effects of such agreements.

We would like to emphasize two broad observations and their policy implications. First, the part of the welfare effect of the policy reform that is associated with imperfect competition in the labor market depends on whether the number of employed persons increases or decreases in the unionized economy. This means, in turn, that the incentives to participate in this type of agreement for a country with imperfect competition in the labor market may either be stronger or be weaker than those of a perfectly competitive economy. In addition, note that the public policies in both countries will, in general, affect the number of employed persons in the economy with a unionized labor market, implying that the effects of policy coordination on the employment in the unionized economy also depend on the preferences and technology in the competitive economy.

Second, we show how the characteristics of the prereform equilibrium may be of considerable importance for the national and global welfare effects of the reform. Although interesting in itself, this also has the practical implication that characteristics of the prereform equilibrium, to a large extent, may determine the incentives, or the strength of the incentives, facing individual countries in their choices of whether or not to participate in international agreements. If each country has made an optimal choice of policy on a national basis prior to policy cooperation, then all welfare effects of cooperation are associated with the transboundary part of the external effect, which is the only aspect of environmental damage that is not internalized at the national level. The results also show that, if the prereform equilibrium is represented by the outcome of a Stackelberg game, the part of the agreement that refers to actions taken by the follower will affect the welfare of both the leader and the follower, whereas the part of the agreement that refers to actions taken by the leader only influences the welfare of the follower. If the environmental damage generated by the follower is not of major importance for the welfare of the leader, then this may imply that the leader is more reluctant to engage in international policy cooperation than the follower, since most welfare effects of such cooperation have already become internalized by the leader.

5. Appendix

Differentiating the social welfare function in (16) with respect to α_1, we obtain (if τ_1, τ_2, b_1, and α_2 remain constant)

$$\begin{aligned}\frac{\partial W}{\partial \alpha_1} &= \frac{\partial N_1}{\partial \alpha_1}\left[u_1^e - u_1^u\right] + N_1\left[\frac{\partial u_1^e}{\partial c_1^e}\frac{\partial c_1^e}{\partial \alpha_1} - \frac{\partial u_1^e}{\partial z_1}\frac{\partial l_1}{\partial \alpha_1} + \frac{\partial u_1^e}{\partial x_1}\frac{\partial x_1}{\partial \alpha_1} + \frac{\partial u_1^e}{\partial x_2}\frac{\partial x_2}{\partial \alpha_1}\right] \\ &\quad + [M_1 - N_1]\left(\frac{\partial u_1^u}{\partial x_1}\frac{\partial x_1}{\partial \alpha_1} + \frac{\partial u_1^u}{\partial x_2}\frac{\partial x_2}{\partial \alpha_1}\right) \\ &\quad + M_2\left[\frac{\partial u_2^e}{\partial c_2^e}\frac{\partial c_2^e}{\partial \alpha_1} - \frac{\partial u_2^e}{\partial z_2}\frac{\partial l_2}{\partial \alpha_1} + \frac{\partial u_2^e}{\partial x_2}\frac{\partial x_1}{\partial \alpha_1} + \frac{\partial u_2^e}{\partial x_2}\frac{\partial x_2}{\partial \alpha_1}\right]. \end{aligned} \tag{39}$$

Differentiating the resource constraints given by (9) and (10) with respect to α_1 gives, if τ_1, τ_2, b_1, and α_2 are held constant,

$$w_1\left[\frac{\partial N_1}{\partial \alpha_1}l_1 + N_1\frac{\partial l_1}{\partial \alpha_1}\right] + t_1\frac{\partial g_1}{\partial \alpha_1} - \frac{\partial N_1}{\partial \alpha_1}\left[c_1^e - c_1^u\right] - N_1\frac{\partial c_1^e}{\partial \alpha_1} - 1 = 0, \tag{40}$$

$$w_2 M_2\frac{\partial l_2}{\partial \alpha_1} + t_2\frac{\partial g_2}{\partial \alpha_1} - M_2\frac{\partial c_2^e}{\partial \alpha_1} = 0. \tag{41}$$

Finally, by solving (40) and (41) for $\partial c_1^e/\partial \alpha_1$, and $\partial c_2^e/\partial \alpha_1$, respectively, substituting into equation (39), using the private budget constraints, and rearranging, we obtain the cost–benefit rule in proposition 1.

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IV

Environmental Policy and Optimal Taxation in a Decentralized Economic Federation

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This paper deals with environmental policy in an economic federation, where each national (lower level) government faces a mixed tax problem. We assume that the federal government sets emission targets, which are implemented at the national level. We also assume that the economic federation is decentralized, meaning that the national governments are first movers *vis-à-vis* the federal government. Our results show that each country uses its policy instruments, at least in part, to influence the emission target. This has several implications: first, the commodity taxes do not satisfy the so-called additivity property often emphasized in earlier literature, and, second, it provides an argument for using distortionary labor income taxation.

Keywords: income and commodity taxation, economic federation, environmental policy

JEL classification: D 62, H 21, H 70

1. Introduction

A considerable amount of research effort has been put into studying so-called transboundary environmental problems. Transboundary environmental damage means that the emissions generated by each country do not only affect the welfare of the domestic residents; they also affect the welfare of residents in other jurisdictions. To deal with such resource allocation problems, some kind of cooperation is generally required. This is so because, in the absence of cooperation, part of the external effects of environmental damage may remain uninternalized, since country-specific objectives can be expected to govern the policies decided upon by national governments. Clearly, the ideas behind policy cooperation have gained much attention also among policy-makers: an indication is the existence of several international arrangements ranging from voluntary agreements between politically independent countries, such as the Kyoto protocol, to arrangements within given

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institutional structures, such as the environmental policy cooperation within the European Union (EU).

This paper analyzes environmental policy as part of an optimal-tax problem facing the member states of an economic federation, which will be designed to reflect some of the characteristics of environmental policy cooperation within the EU. There are (at least) three interesting features that we would like to address.

First, the federal level – to be called the *federal government* in what follows – is weak relative to the lower-level (national) governments,[1] at least in comparison with other economic federations such as the U.S. This is so because the EU is still in the process of being developed, and the member states may already have made commitments to policies based on their own objectives.[2] We will interpret this characteristic to mean that the national governments act as first movers *vis-à-vis* the federal government.

Second, the federal government typically decides upon environmental targets for the member countries, which are implemented at the national level.[3] For instance, the EU decides upon targets with regard to different types of water and air pollutants,[4] which are to be implemented at the national level. In addition, although the rules governing these targets may be the same for all countries involved, differences in the production structure or other characteristics may, nevertheless, imply that the effective targets differ across countries. Similarly, the Burden-Sharing Agreement within the EU,[5] which refers to the distribution of the CO_2 reduction target for Europe, was decided upon at the federal (EU) level, and the resulting national emission targets will be implemented by policies decided upon by each national government.

1 Admittedly, without a proper constitution, European federalism is still in its infancy, and the decision process may, at least to some extent, resemble negotiations between politically independent countries. In the political-science and political-geography literature, the decision-making structure of the EU has been described as "multi-level governance" based on a state-centered setting. Jones and Clark (2001, p. 2) argue that "from this perspective, national governments are the main channels of communication between the EU member states, thereby controlling the overall direction and pace of EU decision-making."

2 In the EU, the Commission may be thought of as representing "the federal level." The political power of the Commission stems from its right to initiate legislation. However, in order to become EU law, its proposals must pass the Council of Ministers with a qualified majority in the case of environmental regulations. In the Council of Ministers, each member acts on behalf of his/her national government. Therefore, given this decision structure, commitments at the national level are likely to affect the policies decided upon by the EU.

3 See Jordan (2005) for a survey of environmental policy-making within the EU.

4 See, e.g., the Commission of The European Communities (2004).

5 Details concerning the Burden-Sharing Agreement can be found in the Commission of the European Communities (2000). See also Marklund and Samakovlis (2003) for an empirical analysis of the incentives underlying the agreement.

Third, if the lower level of government is described as being the first mover, it follows that the lower-level governments may, in part, use their policy instruments in order to influence the emission targets.

Each of these characteristics is part of the model described below. The main purpose of our paper is to understand what these characteristics imply in the context of optimal taxation at the national level.

Earlier research on environmental policy in economies with transboundary environmental problems deals with the formation of coalitions as well as the use of policy instruments to reach common objectives in such coalitions. One body of literature deals primarily with game-theoretic aspects of policy cooperation, in which the incentives underlying the establishment of coalitions are addressed.[6] Earlier studies in this area do not pay so much attention to the question of how to implement a cooperative (or other) arrangement via economic policy in the context of decentralized economies. Another body of literature deals explicitly with the implementation of such arrangements by applying theories of optimal taxation or theories of policy reforms in the context of multi-country model economies.[7] However, although we have gained much insight from earlier research, it has not (in our view) paid sufficient attention to the institutional structure. The welfare effects of public policies, as well as attempts to coordinate policies between jurisdictions, cannot be thoroughly analyzed, if one does not consider the institutional structure in which this policy will be carried out. Earlier research often implies comparisons between a noncooperative equilibrium and a cooperative equilibrium in terms of economic policy. None of these two extreme cases provides a realistic description of the decision structure underlying many practical environmental policy problems, where the outcome often reflects a mixture of national and international policies.

To our knowledge, there are very few earlier studies dealing with environmental policies in the context of a decentralized economic federation with spillover effects (across lower-level jurisdictions) of environmental damage. Silva and Caplan (1997) and Caplan and Silva (1999) analyze different kinds of transboundary environmental problems and associated policies to solve them. These authors consider federal decision structures, involving a federal government and lower-level (e.g., national or regional) governments; the federal government is assumed to control one specific policy instrument (e.g.,

6 See, e.g., Mäler (1989), Barrett (1994), and Carraro (2003).

7 See, e.g., van der Ploeg and de Zeeuw (1992), Aronsson and Löfgren (2000), Aronsson and Blomquist (2003), and Aronsson et al. (2006a). In the first two studies, the only task for the government is externality correction. Aronsson and Blomquist combine externality correction with redistribution, whereas Aronsson et al. analyze how the welfare effects of coordinated environmental policy reforms depend on the characteristics of the prereform equilibrium.

abatement), whereas the lower level of government is assumed to control another (e.g., environmental taxes). In addition, the economic federation may either be centralized or decentralized, depending on which level is able to make credible commitments (and the EU is used to exemplify a decentralized economic federation).[8] In their studies, a major purpose seems to be to characterize the environmental policy outcomes on the basis of (i) whether the economic federation is centralized or decentralized, and (ii) how the control over policy instruments is distributed between the two levels of government.

Our study differs from the papers discussed in the preceding paragraph in several ways. First, we do not consider situations where the control of traditional policy instruments is divided between the two levels of government; we assume, instead, that the targets decided upon by the federal government are implemented by policies decided upon by the lower-level governments. Second, since our paper is related to the literature on optimal nonlinear taxation in economies suffering environmental damage, it also differs from the earlier studies with respect to tax instruments. In our paper, the economic federation consists of two lower-level jurisdictions,[9] which will be referred to as *countries*, and the policy problem facing the government in each such country is a mixed tax problem, where the set of tax instruments contains a nonlinear income tax and linear commodity taxes. This is a reasonably realistic description of the tax structure characterizing many countries. In addition, it means that the use of distortionary taxation is a consequence of optimization; it is not a consequence of restrictions imposed on the policy instruments. We assume that the aggregate consumption of a particular commodity in each country gives rise to an external effect, which, in turn, spills over into the other country. Thus, the model bears some resemblance to the models used in earlier literature on optimal income and commodity taxation under environmental damage, such as Pirttilä and Tuomala (1997) and Aronsson and Blomquist (2003), although these earlier studies did not address the federation structure discussed here.

However, instead of analyzing redistribution as part of the policy package, as in some of the aforementioned papers, we follow Fuest and Huber (1997) and Aronsson and Sjögren (2004a, 2004b) in disregarding motives for using distortionary taxes that apply under perfect competition (such as asymmetric information). Therefore, the presence of market failures constitutes the only reason for using distortionary taxes in our paper. This does not reflect a belief that other motives for using distortionary taxes are unimportant; only that they are well understood from earlier research. Thus, this simplification enables us to concentrate on how the decentralized federal decision

8 See also the related work on public goods by Caplan et al. (2000) and on tax competition by Köthenbürger (2004).

9 Adding additional lower-level jurisdictions does not affect the qualitative results.

structure contributes to the use of income and commodity taxation at the national level.[10]

The outline of the paper is as follows. In section 2, we describe the model and the outcome of private optimization. The federal decision structure, dealing with the policy problems facing the federal government and the lower-level governments, is introduced in section 3. Much attention is paid to the optimal-tax problems facing the lower-level governments – a focus that makes it possible to compare our results with those derived in earlier studies on environmental policy in the context of optimal income and commodity taxation. Section 4 summarizes the results.

2. The Model

Consider an economic federation comprising two separate jurisdictions, denoted by subindices $j = 1, 2$, each of which will be referred to as a *country*. The consumers in each such country are identical, and their number will be normalized to one for notational convenience. Consumer preferences in country j are represented by the utility function

$$u_j = a_j(c_j, x_j, z_j) + \phi_j^j(E_j) + \phi_j^k(E_k) \tag{1}$$

for $k \neq j$, where c will be referred to as a *clean* good and x as a *dirty* good, whereas z is leisure. We assume that c and x are normal goods. Leisure is, in turn, defined as a time endowment, H, less the time spent in market work, l. The function $a_j(\cdot)$ is increasing in each argument and strictly quasi-concave. In addition, the consumption of the dirty good causes environmental damage, E, meaning that $x_j = E_j$ and $x_k = E_k$. The functions $\phi_j^j(\cdot)$ and $\phi_j^k(\cdot)$ are decreasing and strictly concave in their arguments. We also assume that the consumer in country j treats E_j and E_k as exogenous during optimization.

The budget constraint facing the consumer is given by

$$w_j l_j - T_j(w_j l_j) - q_{j,c} c_j - q_{j,x} x_j = 0\,, \tag{2}$$

where w_j is the wage rate and $T_j(\cdot)$ a general income tax, whereas $q_{j,c}$ and $q_{j,x}$ are the consumer prices. The consumer prices are defined as $q_{j,c} = p_{j,c} + t_{j,c}$ and $q_{j,x} = p_{j,x} + t_{j,x}$, where p denotes producer price and t commodity tax. To simplify the analysis, we follow (much of the) earlier literature on mixed taxation by assuming that the wage rate and producer prices are fixed.

The optimal-tax problem to be examined in this paper will be defined in terms of a conditional indirect utility function and conditional demand functions. Therefore, following Christiansen (1984), it is convenient to solve

10 The mechanisms behind the tax structure discussed in the paper would, of course, also be present in a more general framework with redistribution under asymmetric information.

the consumer's optimization problem in two stages.[11] In the first stage, we maximize the utility conditional on the time spent in market work. This problem is written

$$\max_{c_j, x_j} \quad a_j(c_j, x_j, z_j) + \phi_j^j(E_j) + \phi_j^k(E_k)$$

s.t.

$$b_j = q_{j,c}c_j + q_{j,x}x_j \,,$$

where b_j is treated as a fixed income. The solution defines the conditional demand functions

$$x_j = x_j(q_{j,c}, q_{j,x}, b_j, z_j)\,, \tag{3}$$

$$c_j = c_j(q_{j,c}, q_{j,x}, b_j, z_j) \tag{4}$$

and the conditional indirect utility function

$$v_j = v_j(q_{j,c}, q_{j,x}, b_j, z_j, E_j, E_k) \tag{5}$$

for $j = 1, 2$ and $k \neq j$.

In the second stage, the time spent in market work is chosen to maximize the conditional indirect utility function subject to $w_j l_j - T_j(w_j l_j) - b_j = 0$. The first-order condition is written

$$\frac{\partial v_j}{\partial b_j} w_j[1 - T_j'(w_j l_j)] - \frac{\partial v_j}{\partial z_j} = 0\,, \tag{6}$$

where $T_j'(w_j l_j) = \partial T_j(w_j l_j)/\partial(w_j l_j)$ is the marginal income tax rate. This is the standard labor-supply condition and needs no further interpretation.

3. A Decentralized Economic Federation

As we mentioned in the introduction, earlier literature dealing with economic policy in a multi-jurisdictional setting with transboundary environmental problems typically compares a noncooperative Nash equilibrium with a cooperative equilibrium (where the resource allocation is decided upon by a global social planner). What would happen if we were to analyze these two well-known resource allocations within the model set out above? Although the noncooperative Nash equilibrium and the cooperative equilibrium differ with respect to the value the decision-makers attach to the environment (the noncooperative Nash equilibrium only internalizes the domestically created external effect, whereas the cooperative equilibrium fully internalizes the external effects on a global level), they would, nevertheless, share at least two

11 The unconditional solution, which corresponds to a simultaneous choice of c_j, x_j, and l_j, can be derived by substituting the labor supply function derived from equation (6) into the conditional demand functions in equations (3) and (4).

important characteristics with regard to the tax structure. First, the commodity tax structure would obey the so-called additivity property. The additivity property, which is due to Sandmo (1975), means that environmental damage leads to an additive correction term in the tax formula for the externality-generating commodity, while it has no direct effect on the tax formulas for other commodities. Second, the marginal income tax rate would equal zero, implying that the income tax would be equivalent to a lump-sum tax.

In this section, we will show that none of these characteristics apply in the context of a decentralized economic federation, where the emission targets are decided upon by the federal government and implemented at the national level. We assume that the order of decision-making is such that the public policies (at both levels of government) are decided upon before the private agents make their decisions, implying that each level of government recognizes (and incorporates into its decision problem) how the private sector responds to its policy decisions. In addition, as indicated above, we assume that the national governments are first movers *vis-à-vis* the federal government. The federal government behaves as a traditional follower in the context of the public-policy game with one important exception: to be able to define a target reaction function that is consistent with the first-order conditions of the private sector, we assume that the federal government sets the emission targets as if it expects the implementation to be carried out via the commodity tax on the dirty good. This will be explained below.

3.1. The Federal Government

We assume that the objective function of the federal government is the sum of the two country-specific objectives

$$u = \sum_j u_j \,. \tag{7}$$

The constraints[12] facing the federal government are the behavioral equations of the private sector in each country, which can be summarized by the following equations:

$$-\frac{\partial u_j}{\partial c_j}\frac{q_{j,x}}{q_{j,c}} + \frac{\partial u_j}{\partial x_j} = 0 \,, \tag{8}$$

$$q_{j,c}c_j + q_{j,x}x_j - b_j = 0 \,, \tag{9}$$

together with the restriction

$$E_j - x_j = 0 \,, \tag{10}$$

12 In a more general framework, the federal government may also redistribute resources between the countries. We abstract from redistributive policies carried out by the federal government.

for $j = 1, 2$. Equation (8) represents the first-order condition for the commodity mix chosen by the consumer in each country, equation (9) is the private budget constraint, and equation (10) relates the environmental damage to the consumption of the dirty good.

Note that, since the federal government is assumed to choose E_j while at the same time recognizing equation (10), we cannot use equations (8) and (9) to solve for c_j and x_j as functions of $q_{j,c}$, $q_{j,x}$, b_j, and z_j (as we would normally do when analyzing consumer behavior). Therefore, to be able to formulate the federal government's optimization problem, we must make an additional assumption about the trade-offs at the federal level. We assume that the federal government expects each emission target to be implemented via the commodity tax on the externality-generating good; thus, the federal government presupposes that a lower x_j must imply an increase in $q_{j,x}$ along the demand curve for the dirty good.[13] We can then use equations (8) and (9) to solve for $q_{j,x}$ and c_j as functions of $q_{j,c}$, x_j, b_j, and z_j, i.e., $q_{j,x} = \check{q}_j(q_{j,c}, x_j, b_j, z_j)$ and $c_j = \check{c}_j(q_{j,c}, x_j, b_j, z_j)$. By using equation (10) to replace x_j by E_j, the objective function of the federal government is written as

$$\max_{E_1, E_2} \sum_{j=1}^{2} \left[a_j\left(\frac{b_j - \check{q}_j(q_{j,c}, E_j, b_j, z_j)E_j}{q_{j,c}}, E_j, z_j \right) + \phi_j^j(E_j) + \phi_j^k(E_k) \right]$$

for $k = 1, 2$ and $k \neq j$. Using the first-order conditions, we can derive the reaction functions

$$\check{E}_j = \rho_j(q_{j,c}, b_j, z_j) \tag{11}$$

for $j = 1, 2$, which define the targets for the environmental damage as a function of (some of) the national decision variables. Note also that, since E_1 and E_2 are additively separable in terms of the utility functions, the reaction function facing country j will only depend on its own decision variables; not the decision variables of the other country.[14]

13 Technically, this assumption means that $q_{j,x}$ becomes endogenous from the perspective of the federal government, even if the federal government behaves as a follower in other respects. This additional assumption ensures that the behavior of the federal government is consistent with the private first-order conditions. It also appears to be realistic from the perspective of the EU. Although implementation is typically a national decision problem, as indicated above, the Commission seems to support the use of market-based environmental policy instruments; see, e.g., Communication from the Commission (1997). In the context of our model, this is interpreted to mean that the federal government expects that the implementation will be carried out via the commodity tax on the dirty good instead of via the commodity tax on the clean good or the income tax.

14 In a background working paper, Aronsson et al. (2006b), we also briefly discuss the situation, where E_1 and E_2 are nonseparable from each other (although still separable from the other goods) in terms of the utility function.

3.2. Tax Policy at the National Level

We assume that the national governments behave as Nash competitors towards each other, meaning that each national government treats the policy variables of the other country as exogenous. The order of decision-making in vertical space was indicated above; each national government behaves as a first mover *vis-à-vis* the federal government.

By using the conditional demand functions and the conditional indirect utility function defined in section 2, we can write the optimal-tax problem facing the government in country j as

$$\max_{l_j, b_j, t_{j,c}, t_{j,x}, E_j} \quad v_j(q_{j,c}, q_{j,x}, b_j, z_j, E_j, E_k)$$

s.t.

$$w_j l_j - b_j + t_{j,c} c_j(q_{j,c}, q_{j,x}, b_j, z_j) + t_{j,x} x_j(q_{j,c}, q_{j,x}, b_j, z_j) - \bar{g}_j = 0\,,$$

$$E_j - x_j(q_{j,c}, q_{j,x}, b_j, z_j) = 0\,,$$

$$\rho_j(q_{j,c}, b_j, z_j) - E_j \geq 0$$

for $k \neq j$, where $\bar{g}_j$ represents an exogenous revenue requirement. The first constraint is the budget constraint, in which we have used $T_j(w_j l_j) = w_j l_j - b_j$, whereas the second refers to the relationship between the environmental damage generated by country j and the consumption of the dirty good by its resident. These two constraints take the same general form as in earlier studies. The third constraint, on the other hand, is specific to the federal decision structure discussed here. It means that the environmental damage generated by country j must not exceed the target imposed on country j by the federal government, and the assumption that the national government acts as a first mover *vis-à-vis* the federal government implies, in turn, that it can affect the target, $\rho_j(\cdot)$, via some of its policy instruments.

The Lagrangian is written

$$\begin{aligned} L_j = {} & v_j(\cdot) + \gamma_j[w_j l_j - b_j + t_{j,c} c_j(\cdot) + t_{j,x} x_j(\cdot) - \bar{g}_j] + \mu_j[E_j - x_j(\cdot)] \\ & + \lambda_j[\rho_j(\cdot) - E_j]\,, \end{aligned}$$

where γ_j, μ_j, and λ_j are Lagrange multipliers, and the functions $v_j(\cdot)$, $c_j(\cdot)$, $x_j(\cdot)$, and $\rho_j(\cdot)$ were defined above. If we concentrate on the case with a binding emission target constraint,[15] the first-order conditions become

$$l_j : -\frac{\partial v_j}{\partial z_j} + \gamma_j \left(w_j - t_{j,c} \frac{\partial c_j}{\partial z_j} - t_{j,x} \frac{\partial x_j}{\partial z_j} \right) + \mu_j \frac{\partial x_j}{\partial z_j} - \lambda_j \frac{\partial \rho_j}{\partial z_j} = 0\,, \tag{12}$$

15 If the emission target constraint does not bind, then the resource allocation will be equivalent to the noncooperative Nash equilibrium that would follow in the absence of a federal decision structure.

$$b_j : \frac{\partial v_j}{\partial b_j} + \gamma_j \left(-1 + t_{j,c} \frac{\partial c_j}{\partial b_j} + t_{j,x} \frac{\partial x_j}{\partial b_j} \right) - \mu_j \frac{\partial x_j}{\partial b_j} + \lambda_j \frac{\partial \rho_j}{\partial b_j} = 0 \,, \tag{13}$$

$$t_{j,c} : -c_j \frac{\partial v_j}{\partial b_j} + \gamma_j \left(c_j + t_{j,c} \frac{\partial c_j}{\partial q_{j,c}} + t_{j,x} \frac{\partial x_j}{\partial q_{j,c}} \right) - \mu_j \frac{\partial x_j}{\partial q_{j,c}} + \lambda_j \frac{\partial \rho_j}{\partial q_{j,c}} = 0 \,, \tag{14}$$

$$t_{j,x} : -x_j \frac{\partial v_j}{\partial b_j} + \gamma_j \left(t_{j,c} \frac{\partial c_j}{\partial q_{j,x}} + x_j + t_{j,x} \frac{\partial x_j}{\partial q_{j,x}} \right) - \mu_j \frac{\partial x_j}{\partial q_{j,x}} = 0 \,, \tag{15}$$

$$E_j : \frac{\partial v_j}{\partial E_j} + \mu_j - \lambda_j = 0 \,, \tag{16}$$

in which we have used the time constraint, $z = H - l$, to derive equation (12), and Roy's identity to write the first-order conditions for $t_{j,c}$ and $t_{j,x}$ in the form of equations (14) and (15), respectively. Note also that the form of equation (16) is due to the assumption that E_j is additively separable in terms of the utility function. We will now analyze equations (12)–(16) from the perspective of their implications for the tax structure.

3.3. The Shadow Price of the Environment

As in earlier literature, the shadow price of environmental damage divided by the shadow price of the government's budget constraint, μ_j/γ_j, is an important part of the optimal tax structure. This ratio of shadow prices is interpretable as measuring the value that the government in country j attaches to reduced domestic environmental damage. Let $MWP_j^{E_j,b_j} = -(\partial v_j/\partial E_j)/(\partial v_j/\partial b_j)$ denote the marginal willingness to pay by the resident in country j for a small reduction in E_j, whereas $\tilde{c}_j$ and $\tilde{x}_j$ denote the compensated demand functions. To derive an expression for μ_j/γ_j, we will use equations (13) and (16) along with the Slutsky-type formulas

$$\frac{\partial \tilde{c}_j}{\partial E_j} = \frac{\partial c_j}{\partial E_j} + \frac{\partial c_j}{\partial b_j} MWP_j^{E_j,b_j} \,,$$
$$\frac{\partial \tilde{x}_j}{\partial E_j} = \frac{\partial x_j}{\partial E_j} + \frac{\partial x_j}{\partial b_j} MWP_j^{E_j,b_j} \,.$$

Our result is summarized by proposition 1:

Proposition 1 In the context of the decentralized economic federation, the shadow price of the domestic environmental damage divided by the shadow price of the government's budget constraint can be written as

$$\frac{\mu_j}{\gamma_j} = \frac{1}{\sigma_j} \left[MWP_j^{E_j,b_j} - \left(t_{j,c} \frac{\partial \tilde{c}_j}{\partial E_j} + t_{j,x} \frac{\partial \tilde{x}_j}{\partial E_j} \right) + \frac{\lambda_j}{\gamma_j} \left(1 - \frac{\partial \rho_j}{\partial b_j} MWP_j^{E_j,b_j} \right) \right],$$

where $\sigma_j = 1 - \partial \tilde{x}_j/\partial E_j$.

The first part of the formula in proposition 1 is the marginal willingness to pay by the consumer for a reduction of the environmental damage, whereas the second part represents tax-base effects of environmental damage associated with the commodity taxes. Note that the tax-base effects are defined in terms of the compensated demand functions. The reason is that the income tax is optimally chosen; a change in the revenues from commodity taxation will, therefore, be complemented by a corresponding change in the income tax to retain budget balance. These effects are well understood from earlier research. On the other hand, the third part on the RHS (which is proportional to λ_j/γ_j) is novel. This effect is associated with the environmental target decided upon by the federal government, which is also the reason why the formula in proposition 1 differs from the corresponding expression derived in the context of a noncooperative Nash equilibrium without a federal government.[16]

For purposes of interpretation, let us assume that $\lambda_j/\gamma_j > 0$, which appears to be natural considering that a relaxation of the target (if it is binding) is likely to increase the welfare level from the perspective of country j. Then, notice that the third part of the shadow price formula in proposition 1 can be decomposed into two separate effects: a direct effect of E_j on the target-related constraint facing the national government [which is defined conditional on the target function, $\rho_j(\cdot)$] and an indirect effect on the target function via one of the decision variables facing the national government. The direct effect works to increase μ_j/γ_j; it means that the national government is forced to attach a higher value on the environment than it would otherwise have done. As we will see below, this effect works to increase the commodity tax on the dirty good. The indirect effect appears because the national government is a first mover *vis-à-vis* the federal government. If an increase in the private income relaxes (tightens) the target, so $\partial\rho_j/\partial b_j > 0$ (< 0), there is an incentive for the national government to choose a lower (higher) income tax payment for the consumer than it would otherwise have done. This is interpretable as an extra cost (benefit) associated with raising tax revenues, which works to increase (decrease) the marginal cost of public funds in utility terms. As such, it contributes to decrease (increase) μ_j/γ_j. Therefore, the possibility of influencing the environmental target may have important implications for the value attached to the environment by the government.

16 See Aronsson and Blomquist (2003). In their study, μ_j/γ_j is also affected by a self-selection constraint, since they consider redistribution under asymmetric information as part of the decision problem facing each national government. See also the corresponding optimal-tax problem for a one-country model economy addressed by Pirttilä and Tuomala (1997).

3.4. Commodity Taxation

The commodity tax structure is defined by equations (14) and (15). Since we will discuss the role of commodity taxation in the context of an optimal tax structure, in which the income tax is also optimally chosen, we substitute equation (13) into equations (14) and (15). Then, by using the Slutsky condition, equations (14) and (15) can be rewritten as

$$\begin{bmatrix} \frac{\partial \tilde{c}_j}{\partial q_{j,c}} & \frac{\partial \tilde{x}_j}{\partial q_{j,c}} \\ \frac{\partial \tilde{c}_j}{\partial q_{j,x}} & \frac{\partial \tilde{x}_j}{\partial q_{j,x}} \end{bmatrix} \times \begin{bmatrix} t_{j,c} \\ t_{j,x} \end{bmatrix} = \begin{bmatrix} \frac{\mu_j}{\gamma_j}\frac{\partial \tilde{x}_j}{\partial q_{j,c}} - \frac{\lambda_j}{\gamma_j}\left(\frac{\partial \rho_j}{\partial q_{j,c}} + \frac{\partial \rho_j}{\partial b_j}c_j\right) \\ \frac{\mu_j}{\gamma_j}\frac{\partial \tilde{x}_j}{\partial q_{j,x}} - \frac{\lambda_j}{\gamma_j}\frac{\partial \rho_j}{\partial b_j}x_j \end{bmatrix}, \tag{17}$$

where the determinant of the matrix on the LHS becomes

$$|H_j| = \frac{\partial \tilde{c}_j}{\partial q_{j,c}}\frac{\partial \tilde{x}_j}{\partial q_{j,x}} - \frac{\partial \tilde{c}_j}{\partial q_{j,x}}\frac{\partial \tilde{x}_j}{\partial q_{j,c}} > 0\,.$$

By applying Cramer's rule to the equation system (17), we can derive expressions for the optimal commodity taxes (in an implicit form). Consider proposition 2:

Proposition 2 In the context of the decentralized economic federation, the commodity tax structure is characterized by

$$t_{j,c} = \frac{\lambda_j}{\gamma_j}\frac{1}{|H_j|}\left[-\frac{\partial \tilde{x}_j}{\partial q_{j,x}}\frac{\partial \rho_j}{\partial q_{j,c}} + \frac{\partial \tilde{x}_j}{\partial q_{j,x}}\frac{\partial \rho_j}{\partial b_j}\left(\frac{\partial \tilde{x}_j/\partial q_{j,c}}{\partial \tilde{x}_j/\partial q_{j,x}}x_j - c_j\right)\right],$$

$$t_{j,x} = \frac{\mu_j}{\gamma_j} + \frac{\lambda_j}{\gamma_j}\frac{1}{|H_j|}\left[\frac{\partial \tilde{c}_j}{\partial q_{j,x}}\frac{\partial \rho_j}{\partial q_{j,c}} + \frac{\partial \tilde{c}_j}{\partial q_{j,c}}\frac{\partial \rho_j}{\partial b_j}\left(\frac{\partial \tilde{c}_j/\partial q_{j,x}}{\partial \tilde{c}_j/\partial q_{j,c}}c_j - x_j\right)\right].$$

To interpret proposition 2, consider first the special case without a federal decision structure, meaning that $\rho_j(\cdot) \equiv 0$. In this case, we obtain a standard result: $t_{j,c} = 0$ and $t_{j,x} = \mu_j/\gamma_j$, which satisfies the additivity property. However, for our more general model, it is clear that the commodity tax structure no longer satisfies the additivity property – at least not if we recognize that the policy instruments are, in part, used to influence the environmental target decided upon by the federal government. Therefore, although the real shadow price of environmental damage facing the government, μ_j/γ_j, only appears in the tax formula for the dirty good and has no direct effect on the tax formula for the clean good, each tax formula also contains expressions that are proportional to λ_j/γ_j. Thus, these terms reflect that the national government uses income and commodity taxation to affect the environmental target. The basic intuition behind this lack of additivity is that the national government has fewer policy instruments at its disposal than it has variables to control.

Since the pure externality part of the tax formula for the dirty good, μ_j/γ_j, is well understood from earlier research, we concentrate the discussion on the other components of the tax structure, all of which are due to the desire to relax the emission target. Furthermore, we assume that $\lambda_j/\gamma_j > 0$, which is in accordance with our earlier discussions. Consider first the formula for the commodity tax on the clean good, $t_{j,c}$. The first term within the bracket reflects the direct effect of $t_{j,c}$ on the environmental target. Since $\partial\tilde{x}_j/\partial q_{j,x} < 0$, it follows that $\partial\rho_j/\partial q_{j,c} > 0$ (< 0) provides an incentive for the government to choose a higher (lower) $t_{j,c}$ than it would otherwise have done. The intuition is, of course, that this adjustment contributes to relax the emission target.

The second part of the expression within the bracket in the formula for $t_{j,c}$,

$$\frac{\partial\tilde{x}_j}{\partial q_{j,x}}\frac{\partial\rho_j}{\partial b_j}\left(\frac{\partial\tilde{x}_j/\partial q_{j,c}}{\partial\tilde{x}_j/\partial q_{j,x}}x_j - c_j\right),$$

is due to budget-balance arguments: a change in the commodity tax structure may necessitate an adjustment of the income tax, which, in turn, influences the emission target. This part is decomposable into two separate effects. One is a direct budget-balance effect (the terms proportional to c_j). If $\partial\rho_j/\partial b_j > 0$ (< 0), then a lower (higher) income tax payment contributes to relax the emission target. Given the revenue requirement, this constitutes an incentive to adjust the commodity tax structure by increasing (decreasing) $t_{j,c}$, *ceteris paribus*. The other part of the budget-balance effect arises because $t_{j,c}$ affects $\tilde{x}_j$ (a compensated cross-price effect); as such, it may either reinforce or counteract the direct budget-balance effect discussed before. To understand why this information is of importance for the commodity tax structure, recall that the use of $t_{j,c}$ in this model is due solely to the desire to affect the emission target; there is no reason to use $t_{j,c}$ in order to directly distort the consumption of the dirty good. In general, therefore, if $\partial\tilde{x}_j/\partial q_{j,c} \neq 0$, there would be an incentive to adjust $t_{j,x}$ accordingly, so as to keep $\tilde{x}_j$ constant. The direction and strength of this effect are, in turn, dependent upon how the income tax affects the emission target. Let

$$dt_{j,x} = -\frac{\partial\tilde{x}_j/\partial q_{j,c}}{\partial\tilde{x}_j/\partial q_{j,x}}dt_{j,c}$$

be the induced change in $t_{j,x}$ that is required to keep $\tilde{x}_j$ constant as $t_{j,c}$ increases marginally. Because the goods are substitutes[17] in the sense that $\partial\tilde{x}_j/\partial q_{j,c} > 0$, we have $dt_{j,x} > 0$. Then, as can be seen from the formula for the commodity tax on the clean good, if $\partial\rho_j/\partial b_j > 0$ (< 0), this part of the budget-balance effect constitutes an incentive for the government to choose a higher (lower) tax on the clean good than it would otherwise have done. The intuition is that the reduction of the income tax payment made possible by an induced

17 Recall that we are analyzing a conditional demand system, in which there are only two goods, c_j and x_j.

increase in $t_{j,x}$ relaxes (tightens) the emission target, which the government wants to accomplish (avoid).

Turning to the tax formula for the dirty good, notice first that the so-called budget-balance effects – summarized by the second part of the expression within the bracket – are analogous to, and have the same interpretations as, the corresponding terms in the tax formula for the clean good, which were discussed at some length above. Therefore, we concentrate our interpretations to the first term within the bracket. To understand this part of the tax formula, it is necessary to bear in mind that $t_{j,c}$ directly affects the emission target, whereas $t_{j,x}$ does not – a result due to the assumptions underlying the optimization problem of the federal government. This explains the asymmetry between the tax formulas; the tax formula for the clean good contains a direct effect of $q_{j,c}$ on the emission target, whereas the tax formula for the dirty good does not (for obvious reasons) contain a corresponding direct effect of $q_{j,x}$ on the target. To provide some intuition, let us rewrite the first part of the expression within the bracket in the formula for $t_{j,x}$ to read

$$\frac{\partial \tilde{c}_j}{\partial q_{j,c}} \frac{\partial \rho_j}{\partial q_{j,c}} \frac{\partial \tilde{c}_j / \partial q_{j,x}}{\partial \tilde{c}_j / \partial q_{j,c}},$$

where $\partial \tilde{c}_j / \partial q_{j,c} < 0$. Then, on observing that the government has no reason to use $t_{j,x}$ for the explicit purpose of distorting the clean good, it becomes convenient to define (for $\partial \tilde{c}_j / \partial q_{j,x} > 0$)

$$dt_{j,c} = -\frac{\partial \tilde{c}_j / \partial q_{j,x}}{\partial \tilde{c}_j / \partial q_{j,c}} dt_{j,x} > 0$$

to be the increase in $t_{j,c}$ required to keep $\tilde{c}_j$ constant as $t_{j,x}$ increases marginally. Therefore, if $\partial \rho_j / \partial q_{j,c} > 0\,(< 0)$, there is an incentive for the government to choose a higher (lower) commodity tax on the dirty good than otherwise. The reason is, of course, that the government attempts to relax the emission target via the induced change in the commodity tax for the clean good.

3.5. Income Taxation

We argued in the beginning of section 3 that, if our framework is used in the context of traditional models of noncooperative Nash behavior and cooperative behavior, then the marginal income tax rate will be equal to zero (recall that we abstract from asymmetric information). As a consequence, the income tax would be equivalent to a lump-sum tax. However, this result no longer applies in the decentralized economic federation. Consider proposition 3:

Proposition 3 In the decentralized economic federation, the marginal income tax rate is characterized by

$$T_j'(w_j l_j) = \frac{1}{w_j}\left[t_{j,c}\frac{\partial \tilde{c}_j}{\partial z_j} + \left(t_{j,x} - \frac{\mu_j}{\gamma_j}\right)\frac{\partial \tilde{x}_j}{\partial z_j} + \frac{\lambda_j}{\gamma_j}\left(\frac{\partial \rho_j}{\partial z_j} - \frac{\partial \rho_j}{\partial b_j}\frac{\partial v_j/\partial z_j}{\partial v_j/\partial b_j}\right)\right],$$

where $t_{j,c}$ and $t_{j,x}$ are defined in proposition 2.

Notice first that the tax structure of traditional models appears as a special case of the more general model analyzed here. This is so because, if $t_{j,c} = 0$, $t_{j,x} = \mu_j/\gamma_j$, and $\rho_j(\cdot) \equiv 0$, then it must also hold that $T_j'(w_j l_j) = 0$.

Turning to the more general expression for the marginal income tax rate in proposition 3, recall from the commodity tax formulas in proposition 2 that the direct externality-correcting component, μ_j/γ_j, enters additively in the formula for $t_{j,x}$, whereas it does not directly affect the formula for $t_{j,c}$. It follows from the second term on the RHS of the expression in proposition 3 that the use of distortionary income taxation is not associated with externality correction *per se*. Instead, in our model, a nonzero marginal income tax rate will reflect a combination of two motives: (i) the desire to offset distortions due to commodity taxation, and (ii) the desire to relax the emission target. This is intuitively reasonable, as we have fewer effective policy instruments than variables to control.

The first two terms on the RHS, which are proportional to $t_{j,c}$ and $t_{j,x} - \mu_j/\gamma_j$, respectively, are associated with the former motive for using labor income taxation. As we saw in proposition 2, the formulas for $t_{j,c}$ and $t_{j,x} - \mu_j/\gamma_j$ should be designed to relax the emission target. At the same time, the higher each such tax, the more it may distort consumption (as represented by the compensated demand functions), which provides an incentive to adjust the marginal income tax rate accordningly. For instance, the higher $t_{j,c}$ at the second-best optimum, *ceteris paribus*, the higher (lower) will be the marginal income tax rate, if leisure is complementary with (substitutable for) the clean good in the sense that $\partial\tilde{c}_j/\partial z_j > 0$ (< 0). The intuition is that a higher (lower) marginal income tax rate contributes to decrease (increase) the hours of work. The term proportional to $t_{j,x} - \mu_j/\gamma_j$ can be given an analogous interpretation is terms of complementarity or substitutability between the dirty good and leisure.

The third term on the RHS is due to the desire to relax the emission target. It is decomposable into two parts. First, if more use of leisure contributes to relax (tighten) the emission target, so $\partial\rho_j/\partial z_j > 0$ (< 0), there is an incentive to choose a higher (lower) marginal income tax rate than otherwise. Second, if an increase in the private income relaxes (tightens) the emission target, so $\partial\rho_j/\partial b_j > 0$ (< 0), there is an incentive for the government to increase (decrease) the private income, which can be accomplished by a lower (higher) marginal income tax rate.

For the model set out above, we cannot in general determine the sign of the marginal income tax rate. To provide some additional intuition behind the mechanisms involved, let us exemplify by considering the special case, where the non-environmental part of the utility function takes the Cobb–Douglas form, whereas environmental parts are summarized by quadratic loss functions. This means that the direct utility function facing the resident in country j can be written

$$u_j = A_j c_j^{\alpha_j} x_j^{\beta_j} z_j^{\eta_j} - \frac{1}{2}\zeta_j^j [E_j]^2 - \frac{1}{2}\zeta_j^k [E_k]^2 ,$$

where $A_j > 0, \alpha_j > 0, \beta_j > 0, \eta_j > 0, \zeta_j^j > 0$, and $\zeta_j^k > 0$ are constant parameters, whereas $\alpha_j + \beta_j + \eta_j < 1$. The reaction function becomes

$$\rho_j(q_{j,c}, b_j, z_j) = B_j q_{j,c}^{-\hat{\alpha}_j} b_j^{\hat{\alpha}_j} z_j^{\hat{\eta}_j} ,$$

in which $B_j > 0$ is a (country-specific) constant, while $\hat{\alpha}_j = \alpha_j/(2-\beta_j)$ and $\hat{\eta}_j = \eta_j/(2-\beta_j)$. Although this example implies $\partial\tilde{c}_j/\partial z_j < 0$ and $\partial\tilde{x}_j/\partial z_j < 0$, we are still unable to sign the first two terms on the RHS of the tax formula in proposition 3 (since $t_{j,c}$ and $t_{j,x} - \mu_j/\gamma_j$ can be either positive or negative). However, as long as $\lambda_j/\gamma_j > 0$, one can show that the third term in the tax formula (which reflects the incentive to influence the emission target via the income tax) is positive, i.e., with the functional form used here, we have

$$\frac{\partial\rho_j}{\partial z_j} - \frac{\partial\rho_j}{\partial b_j}\frac{\partial v_j/\partial z_j}{\partial v_j/\partial b_j} > 0 .$$

From a technical perspective, this result appears because the effect of z_j dominates the effect of b_j. Therefore, the desire to relax the target provides an incentive for the government in country j to choose a higher marginal income tax rate than it would otherwise have done. The intuition is that a decrease in the hours of work, which reduces the income available for private consumption, will also reduce the environmental damage caused by country j. As a consequence, the federal government relaxes the target for country j, which is precisely the effect that country j wants to accomplish via the marginal income tax rate.

4. Summary and Discussion

This paper deals with environmental policy in the context of a mixed tax problem facing each national government in an economic federation. We assume that the federal government chooses emission targets for the countries, which are implemented at the national level. Each national government treats other national governments as Nash competitors. We also assume that the economic federation is decentralized, meaning that the national governments are first movers *vis-à-vis* the federal government in vertical space. Our model is inspired by the decision structure underlying the environmental policy within the EU.

The idea behind our study is to characterize the optimal tax structure; it is not to establish whether taxes are higher or lower than in a standard model. Thus, we are able to describe why, and how, standard rules for income and commodity taxation are modified. Our results suggest a strategic motive for tax policy not discussed in earlier literature: each country uses its policy instruments, at least in part, to influence the emission target. This has several important implications for the optimal tax structure: first, the commodity taxes do not satisfy the so-called additivity property often emphasized in earlier literature, and, second, it provides an argument for using distortionary labor income taxation.

Clearly, as we indicated in the introduction, European federalism is still in its infancy, meaning that it may not be entirely clear how the behavior at the "federal level" ought to be described. At the same time, the basic issue here is that the lower-level (national) governments are able to commit to their policies, implying that the "federal outcome," however defined, is conditioned on the policy variables decided upon at the national level. As long as this assumption is relevant, our analysis may shed light on the implications for tax policy at the national level of being able, in part, to affect the targets decided upon at the federal level.

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